ASSESSMENT OF THE

STATUS OF FIVE STOCKS OF PUGET SOUND CHINOOK AND COHO

AS REQUIRED UNDER THE
PFMC DEFINITION OF OVERFISHING

TECHNICAL REPORT

For The
Pacific Fisheries Management Council

Prepared By
Puget Sound Salmon Stock Review Group

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDIX TABLES

EXECUTIVE SUMMARY

The Puget Sound Salmon Stock Review Group (PSSSRG) was appointed by the Pacific Fishery Management Council to investigate the reasons the escapement objectives were not achieved for the Skagit spring chinook, Stillaguamish summer/fall chinook, Snohomish chinook, Skagit coho, and Hood Canal coho stocks for the years 1988 through 1990. Conclusions and recommendations of the review group are summarized below.

Chinook Salmon

The chronically depressed status of the chinook stocks considered in this report is likely due to a combination of exploitation rates which are too great and reduced productivity due to degradation of habitat. The excessive exploitation rates may stem in part from the lack of a consistent management objective and the absence of a comprehensive management forum for Puget Sound chinook. The PSSSRG recommends:

- **Create an annual management forum for Puget Sound chinook which establishes a common management objective for troll, sport, and net fisheries in Puget Sound.**
- **Utilize a consistent analytic tool for assessing the impacts of all fisheries upon Puget Sound stocks of chinook.**
- **Evaluate enhancement options which are consistent with natural stock management and can be used to speed rebuilding of depressed chinook stocks.**

Coho Salmon

The primary factors which resulted in the failure of the Hood Canal and Skagit natural coho stocks to achieve escapement objectives were 1) underestimates of the exploitation of these stocks in Puget Sound terminal net fisheries outside of the terminal areas for the Skagit and Hood Canal stocks, 2) preseason forecasts for the Hood Canal stock in 1989 and 1990 which were too great, and 3) underestimates of the exploitation of the Skagit stock in the west coast Vancouver Island (WCVI) troll fishery. Other factors which contributed to the failure to achieve escapement objectives are discussed in the text. The PSSSRG recommends:

- **Establish a management framework, such as the "Stepped Harvest Management Approach", which streamlines the preseason planning process and reduces its dependence upon preseason estimates of abundance and exploitation.**
- **Conduct annual postseason assessments of stock abundance and exploitation rates and use these to improve the run prediction database.**
- **Evaluate and update the Coho Assessment Model based upon the results from the annual postseason evaluation particularly with respect to the level of temporal and fishery stratification used in the model.**

Freshwater Habitat

Specific recommendations of the PSSRG for each of the four rivers or salmon producing areas are discussed in Chapter 2 of this report. Four generally applicable recommendations for actions to correct the declines in freshwater habitat quality are:

- Develop a comprehensive resource and habitat assessment for all watersheds that includes a general inventory of current habitat and the identification of factors limiting fish production and survival.

- Tribal and state fisheries management agencies should develop a coordinated long-term program to monitor the status of fish populations, stream habitat, and the effectiveness of habitat protection and restoration efforts. The program should be established with the goal of improving our knowledge regarding the quantitative relationship between land use, habitat condition, and fish production.

- Local, tribal, state, and federal governments should develop a comprehensive coordinated approach to habitat protection and restoration on a watershed and regional basis.

- The PFMC should request specific action from local, tribal, state, and federal governments to protect and restore critical habitat for stocks of concern.

General Data Needs

The PSSSRG identified the following data needs for both chinook and coho salmon.

- Identify and quantify those factors in the freshwater and marine habitat which limit the productivity of chinook and coho salmon stocks. Initiate programs to protect, rehabilitate, and enhance critical habitat with particular emphasis on the limiting factors.

- Insure that stocks representative of the "overfished" stocks are tagged on an annual basis.

- Review escapement estimation methods, including the stray rates of tagged hatchery indicator stocks, and recommend improvements to the methods as necessary.

- Review the appropriateness of the current escapement goals.

- Continue development of improved preseason forecasts with an emphasis on obtaining direct estimates of total recruitment which include indicators of marine survival.

INTRODUCTION

NOAA's recently published "Guidelines for Fishery Management Plans" (FMP) 50 CFR Part 602 (July 24, 1989) required that the FMPs for each management council contain a definition of overfishing for each managed stock or stock complex covered by the FMP. To meet this requirement, the Pacific Fishery Management Council (PFMC) incorporated an overfishing definition into its salmon FMP by adopting the 10th amendment to the plan.

According to the definition, overfishing is indicated if a salmon stock fails to meet its annual spawning escapement goal or management objective for three consecutive years and if changes in the fishery management regime offer the primary opportunity to improve stock status. The latter provision of the definition was included because it was recognized that the failure to meet escapement goals can result from factors other than those related to fishing. The failure to meet escapement goals for 3 consecutive years is therefore best viewed as an initial indicator that the stock may be in a state of decline and that a thorough review of its status is warranted. To facilitate this review, Amendment 10 requires that the Council appoint a work group to investigate the causes of the apparent shortfall in escapement.

Amendment 10 was implemented in April 1991. The first assessment of chinook and coho stocks specified in the salmon FMP indicated that five stocks in Puget Sound met the definition criterion including Skagit and Hood Canal coho, Skagit spring chinook, Stillaguamish summer/fall chinook, and Snohomish summer/fall chinook (Table 1.1). The Puget Sound Salmon Stock Review Group (PSSSRG) was appointed by the Council and asked to examine the causes which led to the failure in meeting annual spawning escapement objectives for the five specified stocks.

The PSSRG has provided two reports in response to the request from the PFMC. The "Summary Report" provides an overview of the results from the analysis and recommendations of the PSSSRG. This document, the "Technical Report", provides a description of the analytical methods utilized, additional details of the results, and further discussion of the recommendations. Chapter 1 of the report includes an assessment of the status of the five stocks and detailed analyses of harvest impacts on these stocks. Chapter 2 describes factors affecting the general status of salmonid habitat within Washington State, the Snohomish, Stillaguamish, and Stillaguamish rivers, the Hood Canal basin, and the Puget Sound Basin.

Table 1.1. **Comparison of preseason predictions of escapement and postseason estimates for five Puget Sound natural stocks of chinook and coho salmon.**

STOCK	PREDICTED ESCAPEMENT	ESTIMATED ESCAPEMENT	ESCAPEMENT GOAL
Stillaguamish Summer/Fall Chinook			
1988	547	717	2,000
1989	2,000	811	2,000
1990	1,600-2,050	842	2,000
Snohomish Summer/Fall Chinook			
1988	5,250	4,513	5,250
1989	6,341	3,138	5,250
1990	6,205	4,209	5,250
Skagit Spring Chinook			
1988	1,400	2,008	3,000
1989	2,000-4,000	1,853	3,000
1990	3,478	1,902	3,000
Skagit Coho			
1988	24,000[1]	19,000	30,000
1989	19,200[1]	17,000	30,000
1990	23,400[1]	15,000	30,000
Hood Canal Coho			
1988	15,500[1]	11,610	19,100
1989	19,100	15,310	19,100
1990	19,100	6,800	19,100

1/ Annual escapement objective identified during the PFMC process.

CHAPTER 1. ASSESSMENT OF STOCK STATUS

1.1 INTRODUCTION

To provide a framework for the analysis of stock status, the PSSSRG hypothesized that either 1) the recruitment to U.S. fisheries was insufficient to achieve the escapement objective or 2) that errors in management or assessment models resulted in an overharvest of the stock. If recruitment was insufficient to achieve the escapement objective, then subsequent analysis attempted to discern the why the stock was depressed. For example, was survival unusually poor, were exploitation rates on the previous brood(s) too great, or had habitat degradation reduced the productivity of the stock? Conversely, if the escapement objective was not met despite adequate recruitment, the focus of the analysis was the current management system and models. Was the preseason forecast in error, were fisheries not managed as expected, or were model predictions of fishery impacts in error? Chapter 1 of this report details the group's findings and recommendations.

1.2 DATA AND MANAGEMENT SYSTEM

1.2.1 CHINOOK SALMON

1.2.1.1 Database and Stock Assessment Methods

1.2.1.1.1 Escapement Goals

Escapement goals for natural spawners in the Stillaguamish and Snohomish rivers were established using averages of the observed escapements during the 1973-1976 period for the Stillaguamish and during the 1965-1976 period for the Snohomish (Ames and Phinney 1977). The Stillaguamish and Snohomish escapement goals are 2,000 and 5,250, respectively.

The Skagit spring chinook escapement goal is 3,000, which is the average of the escapements estimated from 1959-1968.

1.2.1.1.2 Spawning Surveys and Annual Escapement Estimates

Natural escapements for the Stillaguamish and Snohomish river mainstems are estimated using aerial redd counts which are plotted as a curve, and the area under the curve is calculated to derive a total redd count. The total redd count is converted to an estimate of spawners using average fish per redd values (Ames and Phinney 1977). Spawning levels in tributaries to the Stillaguamish and Snohomish, as well as the Skagit spring chinook escapements, are estimated using either peak counts of redds or peak live and dead adults counted during weekly surveys.

1.2.1.1.3 Run Reconstruction

The database that is currently used for management of Puget Sound stocks of summer/fall chinook is based on a run reconstruction that includes adult fish harvested in the Puget Sound net fisheries during Adult Accounting periods plus the estimated escapement. An Adult Accounting period is defined for each fishing area and approximates the time period when the majority of the catch is comprised of mature fish. For the Puget Sound chinook stocks considered here, the run reconstruction run size is normally less than 25 percent of the age 2 recruitment to fisheries although this does not account for subsequent natural or fishery induced mortality.

The database for spring stocks of chinook salmon is limited to catches in terminal net fisheries and escapement.

1.2.1.2 Forecasts

Preseason forecasts are developed under the Puget Sound Salmon Management Plan by consensus between the Washington Department of Fisheries (WDF) and the Puget Sound treaty tribes. The quantity forecasted is the run size as expressed in the Puget Sound run reconstruction database, i.e., Puget Sound net catch of adult chinook plus escapement which is also referred to as the run entering Area 4B. Separate forecasts are made for each recognized natural and hatchery management unit.

Forecast methods vary among regions and among stocks within regions. For hatchery stocks, the predicted return is usually based on the correlation between the Area 4B run size and the size of the release of juvenile chinook (either weight or numbers) from four years prior to the year being forecasted. For natural stocks, the forecasts are either made in terms of total returns per spawner (generally assuming a simple four year brood cycle) or as the average run size. The forecast methods used each year are generally documented in the Puget Sound Chinook Salmon Forecast and Management Recommendations Reports published jointly by the Puget Sound Tribes through the Northwest Indian Fisheries Commission (NWIFC) and WDF.

1.2.1.3 Management Planning

Currently, there are no tools available to estimate Puget Sound chinook stock specific impacts in mixed stock fisheries. Accordingly, the mixed stock fisheries are managed using criteria that vary between fisheries.

Ocean sport and troll fishing levels are established by the PFMC. These levels are set primarily in response to the status of coastal and Columbia River chinook stocks since the catch of Puget Sound stocks in the PFMC fisheries is assumed to be quite low.

WDF has the goal of managing recreational fisheries in Puget Sound to avoid increasing trends in chinook harvest, except when harvests can be increased without expanding impacts on chinook stocks of concern. Time and area closures and maximum size limits are used in some cases to provide protection to stocks of concern. For example, in recent years the sport fishery in areas 5, 6 and 7 has been subject to a 30 inch maximum size limit. The objective of these measures was to reduce impacts on Puget Sound spring chinook stocks. In general, the Puget Sound sport fishery regulations are set before final preseason forecasts are available. In recent years, some regulations have been modified to address particular problem areas following finalization of the ocean fishery planning process.

Since 1988, Puget Sound treaty Indian troll fisheries, which are located primarily in the Strait of Juan de Fuca, have been managed to keep the total catch on Puget Sound chinook stocks in all treaty Indian troll fisheries at or below recent levels. Allowable impacts of Puget Sound stocks are established before forecasts are available but can be reevaluated inseason after ocean impact and run strength assessments are complete.

Harvest of adult chinook in terminal net fisheries is managed on the basis of the preseason forecasts. The anticipated harvests of adult chinook in fisheries directed at other species or in run size evaluation fisheries are subtracted from the total run size estimate. If harvestable fish remain in the run, then chinook directed fisheries are planned and fishing time is adjusted inseason so that net fishery harvests will not exceed the allowable harvest levels. Where sufficient information for developing inseason estimates of the returning run size is available, net fishery harvest levels are adjusted during the season. For the stocks considered here there has been little opportunity for directed fishing because of weak returns. If run sizes are limiting, efforts are made to minimize impacts in other fisheries.

Managers generally attempt to minimize harvest of immature chinook in net fisheries directed at other species using gear restrictions and area closures.

1.2.2 COHO SALMON

1.2.2.1 Database and Stock Assessment Methods

In order to appreciate the full scope of the current management system it is important to understand the relationship between the historical database and stock assessment methodologies and how the resulting information is used in the annual management cycle (Fig. 1.1). The program described is generally applicable to all Puget Sound coho including Hood Canal and Skagit stocks.

1.2.2.1.1 Habitat Inventory

A comprehensive inventory of Washington streams was developed by the WDF in the early 1970s and compiled into what is commonly known as the stream catalog (Williams et al. 1975). The catalog documents the extent of salmon utilization for all tributaries. Information from the stream catalog was subsequently used to estimate coho smolt production potential and the escapement goals that are still in use today (see below).

When the habitat inventory and production estimates were originally developed they provided a reasonable approach to a difficult problem using the best information available at the time. The immediate problem is that the catalog is out of date. The habitat condition has obviously changed over the last 20 years in response to population growth, timber harvest and other land use pressures. However, there has been no mechanism for systematically updating the catalog data.

There is currently an initiative to update the stream inventory and make it a more interactive system capable of receiving new information. However, the necessary funding has not yet been found. In the meantime, the habitat inventory is still the primary source of information used in establishing natural escapement goals for coho. It is also worth noting that this is one of the few applications of habitat related information to the data management system.

1.2.2.1.2 Escapement Goals

Information on the extent of utilization from the stream catalog was used to estimate coho smolt production potential which was then converted to escapement goals (Zillges 1977). Each tributary section was designated as large (those larger than 6 yards in average width) or small and a smolt production potential was assigned to each. The production rate for large tributaries (2.5 smolts/yard) was based on a report by Lister and Walker (1966) from a five year study on the Big Qualicum River located on Vancouver Island. The production rate for small tributaries (0.42 smolts/square yard) was based on work done in Oregon (Chapman 1965).

The production potential of coho smolts was determined by multiplying the length or area of all tributaries by the appropriate production rate and summing over all tributaries. An exception to this procedure was made in Hood Canal for the Dewatto, Tahuya, Big Mission and Union rivers which were judged to be exceptionally productive because of the high quality of habitat. A subjective decision was made to double the respective production potential estimates for those rivers. The resulting production estimate for Hood Canal was about one million smolts.

The production potential of the Skagit system was also determined by summing the products of the length/area and production rate data. The resulting smolt production estimate was approximately 1,475,000 coho smolts.

Escapement goals for natural coho stocks were calculated by dividing the smolt production estimates by 100 and multiplying by 2. The underlying assumptions were that each female could produce 100 smolts and that the sex ratio would be even (Zillges 1977). The smolt to female conversion was based on work done on Minter Creek in south Puget Sound (Salo and Bayliff 1958). The escapement goals for the Hood Canal and Skagit systems were thus set at approximately 19,100 and 30,000 adults, respectively.

1.2.2.1.3 Spawning Surveys and Annual Escapement Estimates

Escapement estimates are determined annually using live count surveys of index reaches located throughout the region (Flint 1983; 1989). Counts are made weekly on each index section , conditions permitting. At the end of the season the area under the curve method is used to estimate the number of fish-days observed for each index. The individual estimates are then summed to give a single index count for the region.

Escapement estimates for a particular year are derived using a similar index count for a base year and the estimated escapement in the base year as shown below (Zillges 1977):

$$Escapement = \frac{(Present\ Year\ Index)}{(Base\ Year\ Index)} \times (Base\ Year\ Escapement)$$

The base year for Hood Canal is 1965; the base year escapement estimate is 36,600 adults. The estimate was derived using all available stream survey data, fish counts and individual expertise available during the base year. However, the base escapement estimate was an educated guess rather than a rigorous assessment. The standard survey method used in 1965 was based on peak counts which meant that survey reaches were visited once or twice per season rather than every week. There was 12.2 miles of index coverage and 12.8 miles of supplemental coverage in 1965. The original analysis of the data is apparently no longer available.

For the Skagit system, the original base year estimate of 23,149 was replaced with an escapement estimate of 29,184 derived from a tagging study in 1977 (Flint 1983).

1.2.2.1.4 Run Reconstruction

Run sizes are reconstructed post-season using the escapement and Puget Sound commercial net catch data.

Run reconstruction is the computational process of sequentially adding catch to the escapement of each stock beginning with the most terminal areas. Catch composition in each area can be estimated from either the relative abundance of each stock leaving the area or from sources external to the run reconstruction (i.e., genetic stock identification, tagging studies, etc.). The critical assumptions of the technique pertain to the distribution of stocks available to each fishery. Some of these assumptions include: all fish caught in Hood Canal are assumed to have originated there; no Hood Canal fish are taken south of the area 9/10 line; 65 percent of the fish taken in the Strait of Juan de Fuca are of U.S. origin, etc. Similar assumptions are made about the distribution of all Puget Sound natural and hatchery stocks.

Runs are rebuilt to Area 4B only and exclude catches in Canadian or other ocean fisheries, as well as all Puget Sound sport catches. Based on a review of CWT data, the net catch plus escapement estimates incorporated in run reconstruction data base account for roughly half the actual recruitment of each stock.

1.2.2.2 Forecasts

The run reconstruction data base is used to forecast run size at the start of the management cycle for each year. The Science and Statistics Committee (SSC) of the PFMC has recently reviewed Skagit and Hood Canal coho forecast methodologies. Summaries of the available data and a discussion of the methods considered and used in recent years were included in the documentation provided to the SSC (Dygert 1991; Hayman 1991). The forecast methods used each year are generally documented in the Puget Sound Forecast and Management Recommendations reports.

A variety of indicators are reviewed each year including measures of summer low flow, escapement and smolt production (when and where available). The summer low flow measures are the indicators used most often based on the assumption that low flows limit smolt production and subsequent adult returns. However, there is a basic problem in that the indicators do not provide strong and unambiguous relationships and consideration of all indicators often provide conflicting results. Perhaps the greatest shortcoming of current forecast methods is the absence of significant indicators of marine survival that would help account for the considerable variability observed in annual recruitment.

Forecasts have been scrutinized in considerable detail in hopes that improved methodologies can be found. There is general concurrence that a significant problem with the current forecasting process is the necessary reliance on the reconstruction estimates of run size rather than total ocean recruitment. Efforts are being made to address this problem. Although this may provide improved forecasts, it will not necessarily alleviate the significant management problems associated with forecast imprecision.

Once the estimates of Puget Sound run size are resolved, they are expanded to total ocean recruitment for input into the Coho Assessment Model (CAM). The run size estimates are adjusted to account for 1) the reductions in ocean harvest since the base period and 2) the switch from run reconstruction to CWT based estimates of stock composition in the Puget Sound preterminal net fisheries.

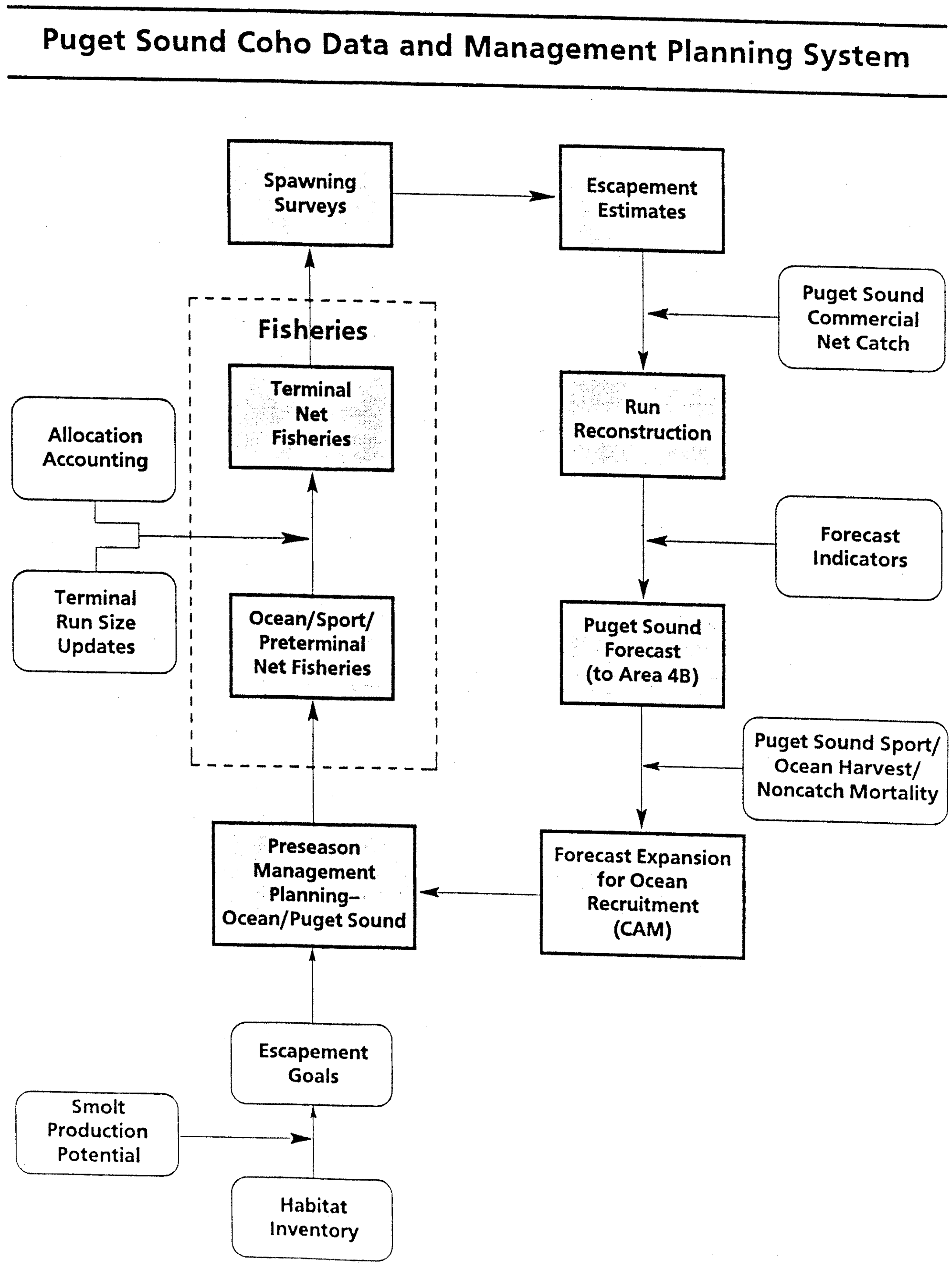


Figure 1.1. Illustration of information flow for data collection, stock assessment, and management planning.

1.2.2.3 Management Planning

1.2.2.3.1 Preseason Management Planning

Much of the preseason planning for Puget Sound coho stocks is done during the PFMC's March and April meetings. The PFMC meetings are to a large extent a negotiation process that is constrained by rules related to allocation and escapement objectives. In some cases, these management constraints are modified in order to maintain what has been characterized as minimal fishery needs. This has been accomplished, in some cases, by adopting an escapement objective for a particular year that is less than the escapement goal of the critical stock.

CAM is used extensively during the preseason planning process to evaluate management alternatives. CAM is a spreadsheet model that utilizes exploitation rates estimated from recoveries of CWTs and the estimates of current abundance described above to predict the catch and escapement for coho stocks of interest.

Weak stocks are identified at the outset and options are considered for meeting minimum escapement requirements for those weak stocks. The focus of the Council planning process is the setting of regulations for the ocean fisheries off Washington, Oregon and California. However, the analysis of options requires that expected catches for all Canadian and Puget Sound fisheries be specified as well. As a result, many of the details of a preseason management plan for all PFMC and Puget Sound fisheries are resolved in this same time frame. It is important to note that specified catches used in the model represent quotas or harvest guidelines that are managed for inseason (i.e., north of Falcon sport and troll fisheries) or estimates of expected catch that may vary substantially from those expected preseason (i.e., Canadian and Puget Sound sport fisheries).

1.2.2.3.2 Inseason Fisheries Management

Ocean sport and troll fisheries and Puget Sound sport fisheries are, for the most part, managed with quotas or time/area restrictions and size and bag limits that are not affected by inseason information related to stock abundance. Preterminal commercial fisheries in the Strait of Juan de Fuca and San Juan Islands are also managed using provisions worked out during the preseason planning process. In recent years, most coho catches in these preterminal commercial fisheries have occurred as incidental takes during fisheries directed at other salmon species. Because of the need to manage for weak Puget Sound stocks, the objective has been to avoid excessive coho impacts while providing adequate fishing opportunity for the other species. Management in the terminal areas is more responsive to inseason information. Inseason updates of abundance are used to adjust the preseason estimate of terminal run size, which allows modification of preseason fishing plans to meet escapement and allocation objectives.

Once the fisheries are completed, spawning surveys are initiated. These in turn provide spawning escapement estimates thus completing the annual management cycle.

1.3 METHODS

1.3.1 Chinook Salmon

The distribution among fisheries of total adult equivalent fishing mortality for the Stillaguamish summer/fall stock and the Skagit spring stock was obtained from unpublished reports of the Chinook

Technical Committee (CTC) of the Pacific Salmon Commission. The total adult equivalent fishing mortality includes sources of non-landed fishing mortality such as shakers and chinook nonretention fisheries. The CTC utilizes recoveries of coded-wire-tags and a computational process referred to as cohort analysis to estimate fishery exploitation rates and adult equivalent fishing mortality (Chinook Technical Committee 1988). Since the Snohomish stock has been tagged irregularly, indirect estimates of the total adult equivalent fishing mortality were obtained from the Pacific Salmon Commission (PSC) chinook model (Chinook Technical Committee 1991a). Recoveries of tagged Stillaguamish wild chinook from the 1980-83 and 1986-88 brood years (Appendix Table 1.1) were summed to look at the distribution of mortalities among fisheries. Recoveries of tagged hatchery spring chinook from the Skagit Hatchery for brood years 1981-87 (Appendix Table 1.2) were summed to look at the distribution of mortality among fisheries for Skagit wild spring chinook.

The PSC chinook model was also used to estimate the potential escapement, a survival rate index, and the adult equivalent exploitation rate for the Snohomish and Stillaguamish stocks. The potential escapement is defined as the escapement (age 3-5) that is predicted to occur in the absence of either a) all fisheries or b) fisheries in the southern U.S. (Washington, Oregon, and California). The potential escapement in the absence of all fisheries was computed by multiplying a stock and age specific maturation rate by the estimated cohort size (reduced for natural mortality) obtained from the PSC chinook model. A similar procedure was used to compute the potential escapement in the absence of southern U.S. fisheries except that the estimated mortality in Alaskan and Canadian fisheries was subtracted from the cohort size.

The survival rate index incorporated in the PSC chinook model provides a measure of the annual variability in brood survival rates. The index is a parameter which is estimated during the calibration of the model by minimizing the difference between the predicted terminal run or escapement (predicted based on brood escapement, a spawner recruit function, and estimated fishing mortality) and the observed terminal run for each stock. An index of less than 1 indicates that survival was lower than predicted by the spawner recruit function.

Since the Skagit spring stock is not included in the PSC chinook model, the total adult equivalent mortality exploitation rate and potential escapement was estimated from cohort analysis of CWT recoveries. The total adult equivalent mortality exploitation rate was obtained from unpublished reports of the CTC. To estimate potential escapement, the CWT recoveries were expanded to represent the Skagit natural stock. The expansion factors were computed as the ratio between the age specific natural escapement and the escapement to the hatchery of tagged fish. An average of the 1988-90 expansion factors was used for 1986 and 1987 since recoveries of tagged fish were limited.

1.3.2 Coho Salmon

The distribution of landed catch and the estimated initial cohort size of Skagit and Hood Canal coho were obtained from recoveries of CWTs and from run reconstruction estimates of terminal area run size estimates. Since a number of tag groups (hatchery and natural) were released within each region, the initial task was to select tag groups which were representative of natural production.

All CWT coho groups that were released into the Skagit River for a given year, that had at least 25 estimated recoveries, were used to model the Skagit stock's distribution in that return year. All groups were used because, when examining dendrograms that compared catch distribution similarity of Skagit groups by year, it was observed that differences between hatchery and wild groups were as great as differences among either the wild or hatchery groups. The few groups that showed very different distributions generally had fewer tag recoveries (which may explain their dissimilarity). Despite the apparent dissimilarity, these groups were also included in the cohort reconstruction (Appendix Tables 1.3-1.5) because they were all also representative of segments of Skagit wild production that were not well represented by the other groups. Data from groups released into Skagit Bay (Swinomish Channel and Oak Harbor Pens groups) were not used in the cohort reconstruction because their production histories are not representative of Skagit wild coho, and because dendrograms showed that some of these groups had greatly dissimilar catch distributions.

In the Hood Canal region, dendrograms indicated that tagged fish released from the George Adams Hatchery had a catch distribution which was dissimilar to that of natural fish from the Skokomish River and from Big Beef Creek. For this reason, only the release groups from the Skokomish River and Big Beef Creek were used in subsequent analyses (Appendix Table 1.6).

In order to expand the tag groups to represent the total production of natural fish from each region, the recoveries were multiplied by a production expansion factor specific to each stock and return year. For Skagit coho, the factor for each year was calculated as the terminal area (Area 8 and the Skagit River) net catch of natural coho that year divided by the estimated number of Skagit River CWTs recovered in the terminal net fisheries. Similarly, for Hood Canal, the factor was computed as the ratio of the catch of all natural stocks in Area 12 (as estimated by the WDF run reconstruction) to the number of recoveries of the representative tag groups. The total expanded escapement in each region was set equal to the post-season estimate published in the WDF run reconstruction, so the terminal run sizes are also the same as those in the WDF run reconstruction, with freshwater sport catch added.

The WDF run reconstruction method currently assumes that all coho caught in areas 12 and 8 are returning to Hood Canal tributaries and the Skagit River, respectively. It also generally assumes that the proportion of natural coho in the terminal harvest in each area is equal to the proportion of the natural coho in the total escapement. Error in either of these assumptions affect estimates of the production expansion factor and the terminal run size, and hence they affect estimates of the initial cohort size and the absolute exploitation rates. Neither of these will affect the estimates of relative distribution of harvest outside of the terminal areas.

Recoveries of the Hood Canal CWT groups in the Hood Canal net fishery were also adjusted to reflect the difference between the terminal net fisheries to which the tagged and untagged fish were exposed to. Natural stocks in Hood Canal are subjected to a gauntlet fishery, with stocks in the more terminal areas generally harvested at a greater rate. Since Big Beef Creek is located near the beginning of the gauntlet, tagged fish returning to this site are not subjected to as great a harvest rate as some other components of the Hood Canal natural stock. In order to account for this, the CWT recovery data were adjusted to match the catch/escapement ratio (as estimated by the WDF run reconstruction) of the natural stock. Freshwater sport fishery catches in both areas were added to the terminal run size, even if there were no CWT recoveries from the fishery.

Cohort abundance and nonlanded fishing mortality of the Skagit and Hood Canal stock were estimated using the NWIFC/WDF cohort analysis program. This program uses algorithms and parameter values which are consistent with the Coho Assessment Model (Scott 1988), and hence, provides a means to directly evaluate preseason predictions of abundance and exploitation rates.

The primary fisheries responsible for deviations from the preseason prediction for the escapement of the

Hood Canal and Skagit natural stocks were selected for which the difference between the preseason prediction and postseason estimate of the exploitation rate multiplied by the estimated recruitment differed by more than 5 percent of the escapement objective. For the Skagit stock, this criterion ranged from 900 fish in 1989 (escapement objective of 18,000 fish) 1989 to 1,200 fish in 1988 (escapement objective of 24,000 fish). Similarly, for the Hood Canal stock, the criterion ranged from 775 fish in 1988 to 955 fish in 1989 and 1990. Within the selected fisheries, the causative factor for the deviation was partitioned into 1) a deviation from the expected total catch (all stocks) in the fishery, 2) an error in the model prediction of the impact of the fishery upon the stock, or 3) both factors 1 and 2.

The partitioning process provides a means to more specifically identify the cause of the deviation from the preseason prediction. Note that errors resulting from factor 1 are associated with either mismanagement of fisheries with quotas or poor predictions of the catch in fisheries with only incidental catch. Errors resulting from factor 2 are associated with either poor predictions of recruitment or the performance of the prediction model (CAM).

The selection and partition process may be expressed algebraically as follows. Let

E : Escapement objective for stock;
A : Actual catch of all stocks in fishery;
P : Predicted catch of all stocks in fishery;
C : Postseason estimate of catch of stock in fishery;
N : Postseason estimate of cohort size;
u : Predicted exploitation rate of stock in fishery;
v : Postseason estimate of exploitation rate of stock in fishery.

A fishery is selected if

$$N \times (v - u) > .05 \times E$$

Factor 1, a deviation from the predicted catch of all stocks, is indicated if

$$\frac{C}{P} \times (A - P) > .05 \times E$$

Factor 2, a deviation resulting from an error in the model estimate of the impact of the fishery on the stock, is indicated if

$$(v - (\frac{A}{P}) \times u)) \times N > .05 \times E$$

A second type of analysis of the CWT recoveries was conducted to compare the harvest rate on each of the stocks with estimates of the rate associated with the maximum sustainable harvest (MSH). Since analyses reported in the literature typically include only catch and escapement recoveries, the harvest rate index was computed by simply dividing the catch recoveries by the sum of the catch and escapement recoveries. In addition, the tag codes selected for this analysis were limited to those for which escapement estimates existed (Big Beef Creek in Hood Canal and the Skagit Hatchery on the Skagit River). To account for tagged fish which did not return to the Skagit Hatchery (strays to natural spawning areas), the estimated escapement of the Skagit Hatchery tag groups was increased by 10 percent.

The harvest rate index may differ from the exploitation rates discussed previously since 1) the exploitation rates are expressed relative to a cohort size and 2) the exploitation rates were computed under the assumption that estimates of natural escapement are unbiased. It is possible (particularly in the Skagit River) that the estimates of natural escapement are significantly underestimated. Because of this, it may be more accurate to estimate the harvest rate index from catch and escapement recovery data taken only from hatchery tag groups (or tag groups which have complete enumeration of escapement). Presumably, the hatchery rack escapements would be estimated more accurately than the wild escapements, although, as with chinook, significant straying of hatchery coho would cause an overestimate of the exploitation rate.

1.4 REVIEW OF STOCKS

1.4.1 STILLAGUAMISH RIVER

1.4.1.1 Introduction

The Stillaguamish River originates in the Cascade Mountains and drains into Puget Sound at Port Susan and Skagit Bay, near the city of Stanwood (Figs. 1.2 and 1.3). The watershed encompasses approximately 684 square miles and contains well over 975 linear miles of stream. Annual discharge is the fifth largest in the Puget Sound area. Average annual rainfall varies from 35 to 50 inches across the watershed. The river generally flows in an east to west direction and can be broken into three general parts: the North Fork, South Fork and mainstem Stillaguamish, each containing numerous tributaries.

1.4.1.1.1 Production

The Stillaguamish River contains both spring and summer/fall chinook. The two races are differentiated by adult migration timing and the areas and time when spawning takes place. The spring chinook run has declined from historic levels, and the current status of the spring chinook run is unknown. Only the summer/fall run will be considered in the remainder of this section. The average terminal run for the Stillaguamish summer/fall stock from 1986-1990 was 1,800 fish.

Scattered reaches throughout the accessible length of the North Fork, South Fork, and mainstem Stillaguamish, downstream to river mile 6.0, are utilized by chinook for spawning. A particularly important reach of river that commonly receives a considerable amount of spawning lies between river miles 22 and 32 on the North Fork. River reaches downstream of spawning areas are important to natural chinook production because these areas are used for rearing and migration by juveniles, and migration and holding areas by mature adults. Upstream reaches are also important for natural production.

In the 1960s and early 1970s some summer/fall chinook from South Puget Sound were stocked into the Stillaguamish system. Since brood year 1986 the Stillaguamish Tribe has maintained a supplementation program using wild broodstock from the North Fork Stillaguamish. Eggs are taken from natural spawners, incubated and short-term reared at the Stillaguamish tribal facility, and the fry are released back into natural habitats. All fish receive a coded-wire tag before release to serve as an indicator stock for purposes of implementing the Pacific Salmon Treaty. The desired level of this program is 200,000 fry release per year, but actual releases have ranged from 24,000 to 130,000 (1986 through 1990 brood years). Preliminary indications are that the 4-year-old return from the 130,000 release contributed a substantial fraction of the spawning escapement to the Stillaguamish River in 1991. Due to improved broodstock capture methods, more than 200,000 eggs were taken for this project for the 1991 brood year.

1.4.1.1.2 Terminal Area Management

The Stillaguamish and Snohomish rivers are adjacent drainages that share a common terminal marine area. They are managed as a single allocation unit. Within the Stillaguamish/Snohomish terminal area there are wild chinook stocks returning to each of the rivers and hatchery chinook runs returning to Tulalip Bay and the Skykomish hatchery in the Snohomish system. There are both net and sport fisheries in the area. None of the terminal area chinook fisheries in the Stillaguamish/Snohomish region is managed using inseason run size information at the present time because directed net fisheries are generally closed during the period when the bulk of the natural runs pass through the terminal area.The terminal area is subdivided into several management areas: Area 8A, where Stillaguamish, Snohomish, and Tulalip Bay stocks are mixed, and three extreme terminal areas where Stillaguamish, Snohomish, and Tulalip Bay stocks can be separately targeted (Fig. 1.3). Since 1985 no net fisheries have been opened in Area 8A to target on chinook stocks due to the depressed status of the Stillaguamish and Snohomish natural runs. Chinook are still harvested in Area 8A incidental to fisheries targeted at pink and coho salmon. The average annual harvest of chinook[1] in net fisheries in Area 8A has declined from 12,178 during the 1979-83 period to 4,157 during the 1986-90 period.

Since 1983 there have been no net fisheries directed at chinook in the Stillaguamish River. Some chinook are harvested incidental to fisheries directed at pink and coho salmon in the river. The average annual net fishery harvest of chinook in the Stillaguamish River has declined from 370 during the 1979-82 period to 22 during the 1986-90 period. There have been no significant net fisheries opened in the Snohomish River in recent years. There is also a net fishery in Area 8D (Tulalip Bay plus some areas outside the bay) which targets on hatchery chinook returning to Tulalip Bay. This area did not exist as a separate area prior to 1985. The average Area 8D chinook harvest in the 1986-90 period in Area 8D was 2,902.

Terminal area sport fisheries occur in WDF punch card Area 8-2 and in the Stillaguamish and Snohomish rivers. Currently the Stillaguamish River remains closed to sport harvest until October 1 each year unless there is pink salmon harvest opportunity in the river in which case the opening date is August 16. In either case, the retention of chinook salmon is not allowed in Stillaguamish River sport fisheries. The

[1] Net fishery chinook harvest numbers include only chinook landed during the adult accounting period established for each area. Chinook caught outside of this period are assumed to be immature, or blackmouth, chinook and to be from a mixture of stocks.

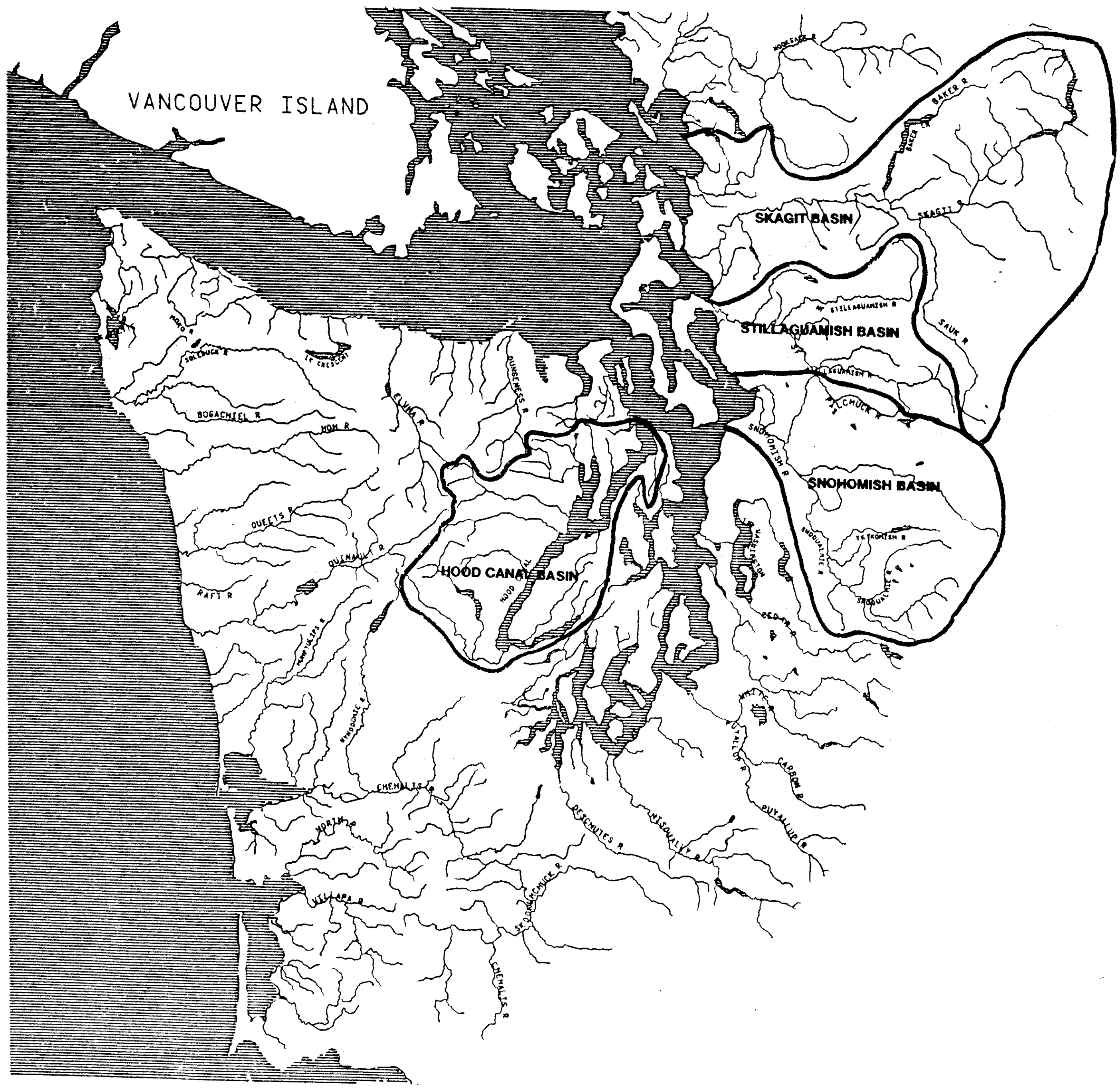


Figure 1.2. **Location of Stillaguamish, Snohomish, and Hood Canal drainages within Puget Sound.**

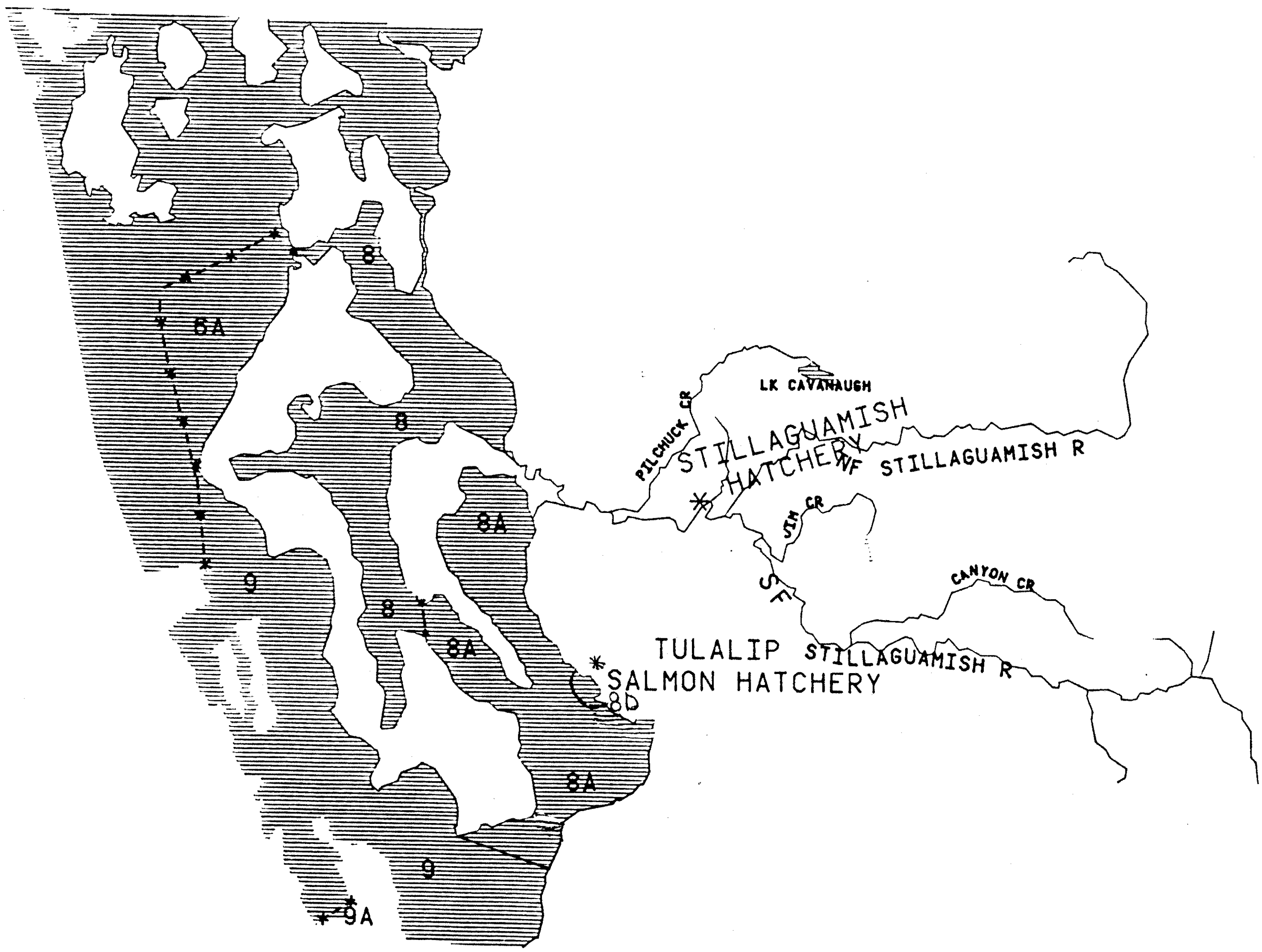


Figure 1.3. **Detailed map of Stillaguamish River and Area 8A.**

Snohomish River opens annually on July 1 and the retention of chinook salmon is allowed. Area 8-2 is opened for sport fishing the entire year, except for a closure in Port Susan to protect the Stillaguamish chinook stock. Currently Port Susan is closed April 16 through August 31. The average annual estimated sport harvest of chinook in the Stillaguamish River has declined from 23 in the 1981-84 period to 4 in the 1985-88 period. The average annual estimated sport harvest of chinook in the Snohomish system was 290 in the 1981-84 period and 236 in the 1985-88 period. The average annual estimated sport harvest of chinook in WDF punchcard Area 8[2] was 8,121 during the 1981-84 period and 9,797 during the 1985-88 period.

1.4.1.2 Stillaguamish Summer/Fall Chinook Assessment

1.4.1.2.1 Distribution of Fishing Mortality

Aggregated tag recovery information for the Stillaguamish summer/fall stock is summarized in Table 1.2.

Table 1.2. Distribution of adult equivalent fishing mortality for the Stillaguamish summer/fall chinook. North net includes areas 4B, 5, 6C, 6, 7 and 7A.

	ALASKA	CANADA	PFMC	PUGET SOUND			
BROOD	ALL	ALL	SPT/TR	TROLL	NORTH NET	OTHER NET	Sport
1980	2	47	0	0	1	7	26
1981	23	70	0	0	1	7	10
1982	0	135	0	0	11	13	48
1983	14	75	0	0	0	12	30
1986[1]	0	178	0	19	4	32	86
1987[2]	5	300	0	30	9	37	52
1988[3]	0	34	0	0	0	28	3
Total 1980-86	39	505	0	19	17	71	200
Percent	4.6%	59.3%	0.0%	2.2%	2.0%	8.3%	23.5%

[1] Incomplete brood; ages 2 through 4 included in the analysis.
[2] Incomplete brood; ages 2 and 3 included in the analysis.
[3] Incomplete brood; age 2 included in the analysis.

[2] The estimated sport catch numbers for punchcard Area 8 include chinook from many stocks other than the Stillaguamish and Snohomish stocks and include blackmouth as well as adult chinook.

The CWT distribution analysis indicates that Canadian and Alaskan fisheries account for 60 to 65 percent of the fishing mortality on this stock. Puget Sound preterminal net and troll fisheries account for about 4 percent of the fishing mortality. Between 20 and 25 percent of fishing mortality is accounted for by the Puget Sound sport fishery. The terminal area net fishery accounts for 10 percent or less of the overall fishing mortality. The result of this analysis was comparable to a similar analysis conducted using the Pacific Salmon Commission (PSC) chinook model.

The distribution of fishery impacts on this stock appears to be stable over time, with the exception of the troll fishery in the Strait of Juan de Fuca. This fishery did not exist at its current level at the time the 1980-1983 brood CWT's were out and, as a result, there were no recoveries in that fishery from the earlier broods. Approximately 6 percent of the recoveries from the 1986 brood tags (the only nearly complete brood year for the more recent tag codes indicates that this fishery may account for 6 percent of the fishing mortality on the Stillaguamish summer/fall chinook stock. As further years of tag data become available, the estimated effect of the Juan de Fuca troll fishery on this stock can be made more precise.

One very important result of this analysis is that the ocean sport and troll fisheries directly managed by the PFMC appear to have little impact on the Stillaguamish summer/fall chinook stock.

1.4.1.2.2 Potential Escapement

The potential escapement of the Stillaguamish summer/fall chinook stock after Alaskan and Canadian fisheries was approximately 50 percent of the escapement goal (2,000) in the years 1988 through 1990 (Fig. 1.4A). The potential escapement ranged from 906 fish in 1988 to 1,042 fish in 1990. The total potential escapement (no fishing) was also less than the escapement goal, ranging from 1,111 to 1,294 fish.

No long term trend was evident in the potential escapement for the Stillaguamish stock. The total potential escapement was greatest from 1985 through 1987, but even then approximated the goal only if all fisheries, including Alaska and Canadian, were assumed closed.

1.4.1.2.3 Stock Productivity

Estimates of stock productivity indicate that survival rates were greatest for the 1981 through 1983 broods (Fig. 1.4B). The survival rates for subsequent broods have been substantially reduced. The average survival rate for brood years 1984 through 1987 was approximately 70 percent less than the average estimated for the 1981 through 1983 broods.

1.4.1.2.4 Adult Equivalent Exploitation Rates

Adult equivalent exploitation rates were near the maximum sustainable harvest (MSH) level for this stock during the overfishing review period (Fig. 1.4C). The rates ranged from 49 to 51 percent during this time period and the average rate of 50 percent was equal to the estimated MSH exploitation rate for this stock.

The adult equivalent exploitation rates have declined substantially since the early 1980s. The average exploitation rate for the years 1980 through 1984 was 65 percent, 20 percent greater than the MSH level. Since the initiation of the PSC fishing regimes in 1985, the average adult equivalent exploitation rate has been equal to the MSH level.

1.4.2 SNOHOMISH RIVER

1.4.2.1 Introduction

The Snohomish River watershed covers approximately 1,780 square miles and is the second largest drainage system in the Puget Sound Region (Fig. 1.5). The basin's high annual discharge is the second largest of all the rivers draining into Puget Sound. The drainage system generally flows in an east to west direction originating on the Cascade Mountain divide and draining into Puget Sound at the city of Everett. It contains well over 2,718 linear miles of stream and consists of two principal rivers, the Skykomish and Snoqualmie, which join upstream of the town of Snohomish to form the lower Snohomish River.

1.4.2.1.1 Production

Snohomish River spring chinook are now a remnant run which is not managed for and may be extinct. Formerly, the fish utilized primarily the upper accessible limits of the Skykomish and Snoqualmie Rivers, as well as some of the major tributaries to these two river systems, for spawning.

The Snohomish River supports the third largest natural stock of summer/fall chinook in Puget Sound. From 1986-1990, terminal run sizes averaged 7,600 fish. Summer/fall chinook spawn extensively throughout the accessible length of the Skykomish and Snoqualmie Rivers, as well as in the Snohomish River downstream to the city of Snohomish. In addition to mainstem areas, tributaries to each of these rivers also receive spawning. In general, summer/fall chinook spawning primarily occurs in the lower reaches of the drainage. Summer/fall chinook are known to utilize the South Fork Skykomish and its major tributaries, the Beckler, Foss and Miller Rivers. These chinook also use the North Fork Skykomish, Wallace, and Sultan Rivers, as well as Woods, Elwell, and Proctor Creeks. Summer/fall chinook utilize the Snoqualmie and its major tributaries. Spawning in the Snoqualmie primarily occurs above the town of Duvall for eleven miles. Major tributaries that receive spawning include the Raging and Tolt Rivers, and Tokul, Cherry and Griffin Creeks. Spawning occurs in the Snohomish from the confluence of the Skykomish and Snoqualmie, downstream 6.5 miles to the city of Snohomish. The Pilchuck River, a major tributary to the Snohomish is also utilized by spawning summer/fall chinook.

The WDF Skykomish Hatchery, located at the confluence of the Wallace and Skykomish Rivers, produces chinook for yearling release, fall release, and fingerling release. Release levels have declined from approximately 65,000 pounds (1981, 1982 brood year average) to less than 25,000 pounds (1986 - 1988 brood year average). This reduction is largely due to insufficient availability of broodstock at the hatchery due to lower than anticipated survivals. In recent years, the production of hatchery chinook from the Snohomish system has been approximately one-quarter to one-third the production of wild chinook from the system. Hatchery-produced chinook strays may be influencing estimates of natural chinook production in the Snohomish system, but a full investigation of this hypothesis has not yet been conducted.

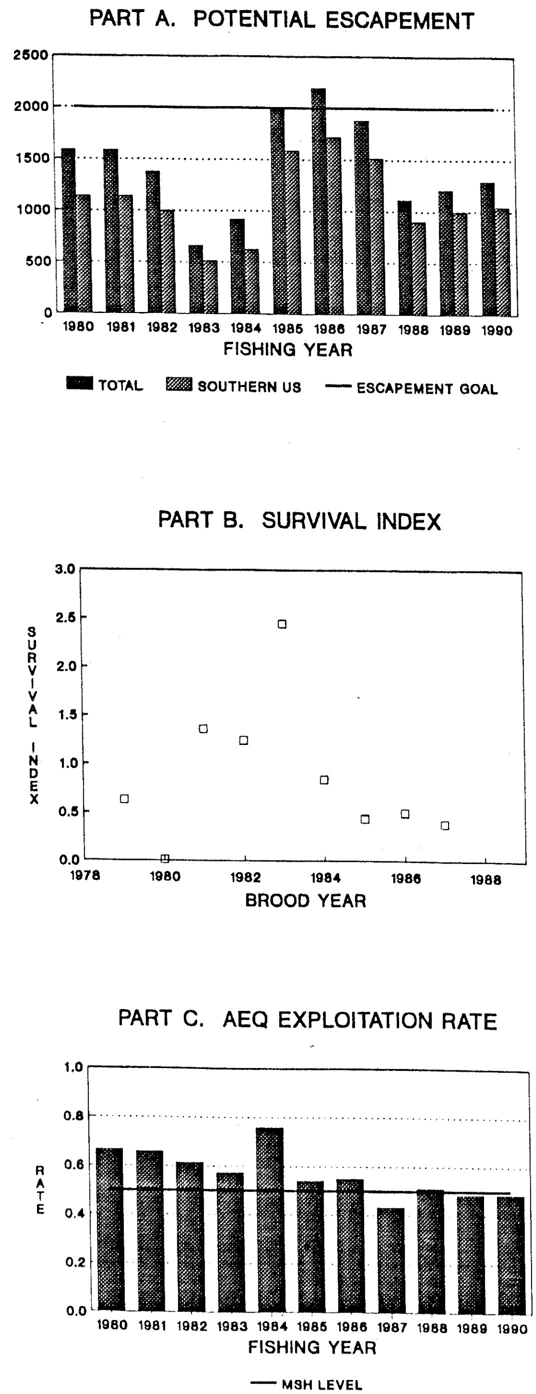


Figure 1.4. **Potential escapement, stock productivity, and adult equivalent exploitation rates for the Stillaguamish stock.**

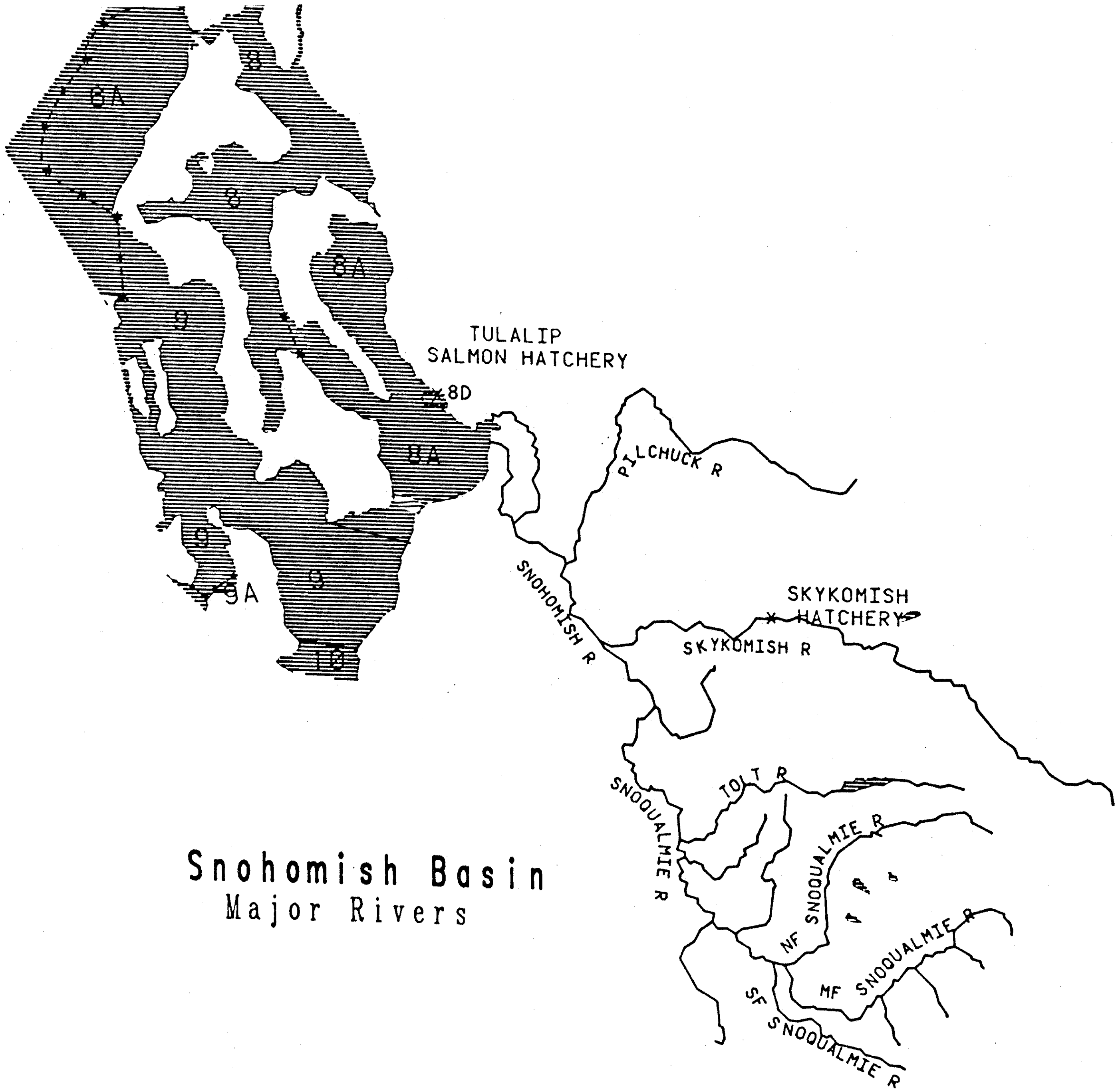


Figure 1.5. **Detailed map of Snohomish River and Area 8A.**

1.4.2.1.2 Terminal Area Management

The Stillaguamish and Snohomish rivers are adjacent drainages that share a common terminal marine area and are managed as a single allocation unit. Management of the common terminal area is described in Section 4.1.1.

1.4.2.2 Snohomish Fall Chinook Assessment

1.4.2.2.1 Distribution of Fishing Mortality

There are insufficient coded wire tags available from the Snohomish system to do a direct analysis of fishery impacts on the Snohomish wild chinook similar to the one above for the Stillaguamish stock. As a substitute, we used total fishing mortality from the PSC model to look at the distribution of Snohomish wild chinook mortality among fisheries (Table 1.2).

Canadian and Alaskan fisheries account for over 50 percent of the mortality on this stock. Puget Sound net fisheries account for about 40 percent of the mortality while the Puget Sound sport fishery impacts account for another 5 to 10 percent. The impacts of the ocean sport and troll fisheries under the jurisdiction of the PFMC are negligible.

Table 1.3. Distribution of adult equivalent fishing mortality for the Snohomish summer/fall chinook. North net includes areas 4B, 5, 6C, 6, 7 and 7A.

	ALASKA	CANADA	PFMC	PUGET SOUND			
BROOD	ALL	ALL	SPT/TR	TROLL	NORTH NET	OTHER NET	Sport
1980	473	15,351	31	NI	379	7,369	1403
1981	472	14,049	31	NI	364	7,315	1302
1982	444	10,455	29	NI	339	5,996	1097
1983	352	8,847	28	NI	248	5,843	994
1984	349	8,506	18	NI	148	5,349	914
1985	179	5,169	21	NI	137	4,388	785
1986	167	4,334	22	NI	162	4,176	689
1987	147	4,286	21	NI	117	2,152	678
1988	125	3,418	9	NI	151	3,124	579
1989	105	3,132	20	NI	52	3,292	692
1990	160	3,232	10	NI	38	4,198	647
Avg. 1984-90	176	4,582	17	NI	115	3,811	712
Percent	1.9%	48.7%	0.2%	NI	1.2%	40.5%	7.6%

NI = This fishery is not included in the analysis.

1.4.2.2.2 Potential Escapement

The potential escapement for the Snohomish fall stock exceeded the escapement goal (5,250) in each of the three years during the overfishing review period (Fig. 1.6A). During this period, the potential escapement ranged from 6,500 to 8,500 fish after accounting for fishing mortality in Alaskan and Canadian fisheries. Total potential escapement (no fishing) ranged from 7,400 to 9,900 fish.

Although the potential escapement was greater than the escapement goal, the harvest of the Snohomish stock in southern U.S. fisheries exceeded the harvest level which would have allowed the stocks to achieve the escapement goal. The potential escapement and the escapement goal of 5,250 indicate that an adult equivalent harvest of 1,200 to 3,200 fish was available to southern U.S. fisheries. Estimated adult equivalent harvests in these fisheries exceeded this range in each year, ranging from approximately 3,500 to 4,500 fish.

The number of Snohomish chinook available for harvest has declined by approximately 50 percent since 1980 (Fig. 1.6A). The potential escapement declined continuously from 1980 to 1987. No trend is apparent for the three years since that time. The average potential escapement for the years 1988 to 1990 is 8,800 fish, which is approximately equal to the estimated value for 1987.

1.4.2.2.3 Stock Productivity

The survival index for the Snohomish chinook stock indicates that survival rates for recent brood years have declined from the rates observed in the broods from the early 1980s (Fig. 1.6B). Although year to year variability in the rates exists, a long term trend toward reduced survival rates is evident. The average value of the index for the last three brood years (1986-1988) is approximately 35 percent less than the index for the first three brood years (1979-1981) in the time series.

1.4.2.2.4 Adult Equivalent Exploitation Rates

The estimated adult equivalent exploitation rates for the Snohomish chinook stock exceeded the MSH level for 9 of the 11 years during the period 1980 through 1990 (Fig. 1.6C). The estimated rates ranged from 57 to 79 percent, with an average of 70 percent. This is approximately 11 percent greater than the estimated MSH adult equivalent exploitation rate of 62 percent.

Imposition of the PSC management regime appears to have reduced the adult equivalent exploitation rates. The average rate was 78 percent for the years 1980 through 1984 (pre PSC management) and 64 percent for the years 1985 through 1990. However, the exploitation rates have exceeded the MSH adult equivalent exploitation rate for four of the six years with the PSC management regime.

1.4.3 SKAGIT RIVER

1.4.3.1 Introduction

The Skagit River is located in Northern Puget Sound midway between Seattle, Washington and Vancouver, British Columbia (Fig. 1.7). It drains Puget Sound's largest basin, with an area of over 3000 square miles and an average discharge of over 16,000 cfs (one third of the freshwater inflow to Puget Sound), and it is, next to the Columbia, the second largest river system in the state of Washington in terms of annual discharge. The Skagit River contains 162 miles of mainstream river, with its origin in

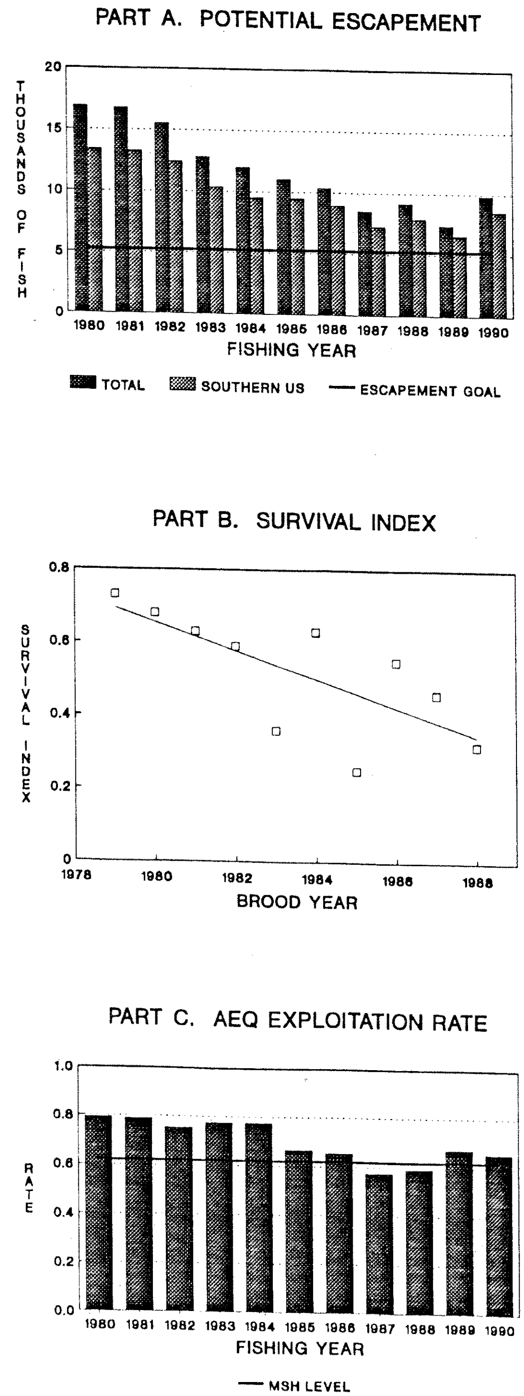


Figure 1.6. **Potential escapement, stock productivity, and adult equivalent exploitation rates for the Snohomish stock.**

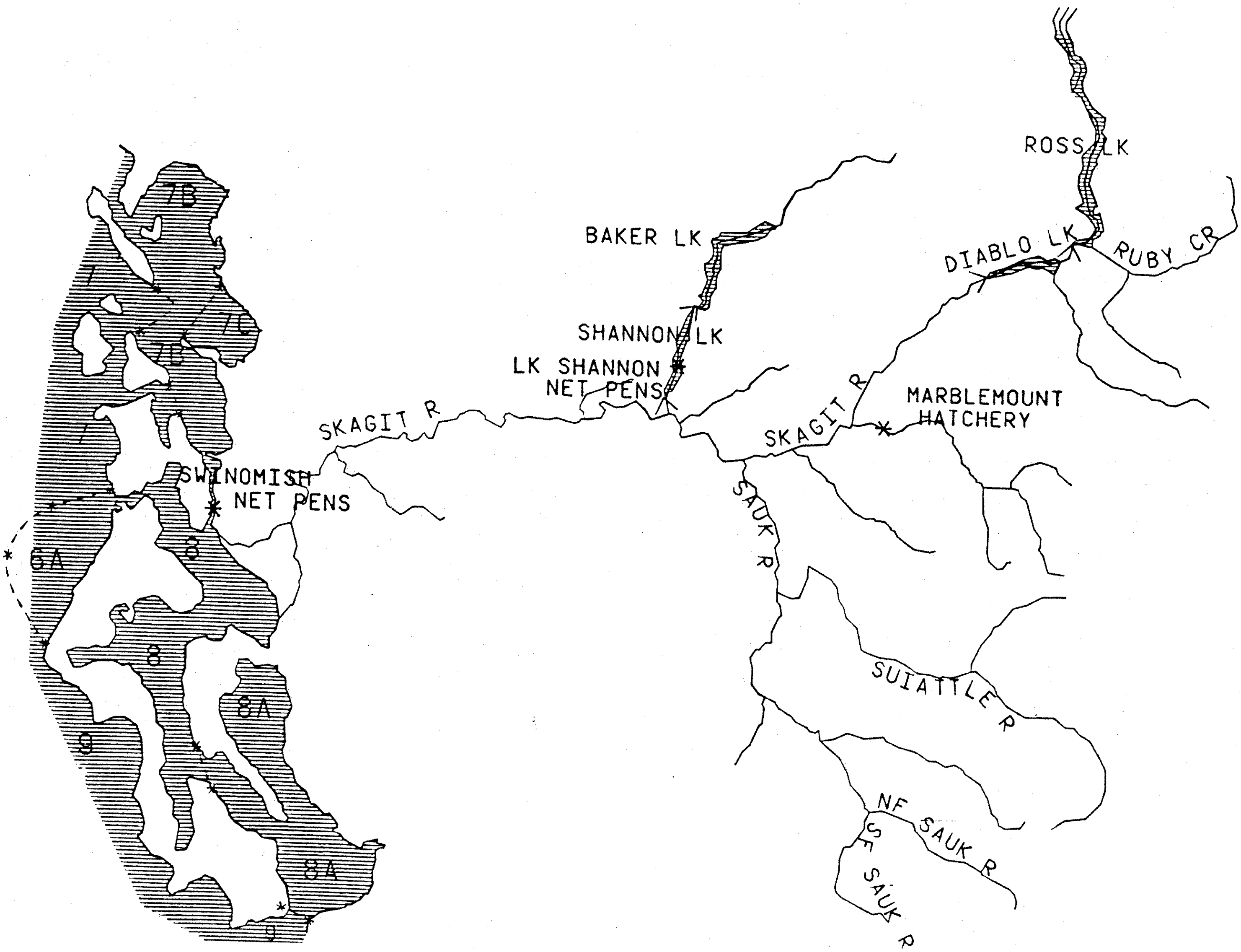


Figure 1.7. **Detailed map of the Skagit River and Area 8.**

the Coveole Mountains of British Columbia. Major tributaries of the Skagit are the Baker, Sauk-Suiattle, and Cascade Rivers.

Anadromous fish are blocked near river mile (RM) 96 by Gorge Dam, and near the mouth of the Baker by Lower Baker Dam. There is, however, a trap-and-haul facility to transport fish above the Baker dams. In the upper reaches of the watershed, the land is primarily forested and moderately steep gradient; the main land use in this area is forestry. Below the confluence with the Sauk the valley broadens and flattens, and this area is used extensively for agriculture.

1.4.3.1.1 Skagit Spring Chinook

Production: The spring chinook run in the Skagit River is the largest remaining natural spring chinook stock in Puget Sound, and had an average terminal run size of 2,100 fish from 1986-1990. Skagit spring chinook were originally defined according to timing of entry to the river, timing of spawning and spawning location. Spring chinook are defined as those chinook caught before the summer/fall chinook management period (which begins about June 16 in Skagit Bay), and those chinook that spawn in the Suiattle, Upper Sauk, and Upper Cascade. Recent research indicates that timing and spawning location do not adequately separate the stocks and that spring and summer/fall stocks do mix to some unknown extent. At the Skagit Hatchery, hatchery "spring chinook" are those that are descended from Suiattle broodstock. This hatchery is the only facility on the Skagit that produces spring chinook. The spring chinook program started with the 1977 brood, but it was constrained for many years by the poor return rate to the hatchery. Improvements to the hatchery fish capture facility were made after the 1987 return, and rack returns, which had been only a handful each year, increased to 100-300 each year. Smolt plants also increased, beginning with the 1985 brood, from less than 50,000 per year to usually more than 100,000 per year. Until 1988, most of the broodstock was taken from the Suiattle spawning grounds, but no wild broodstock has been needed since 1989. As a result, the hatchery run which, until recently, was only a minor portion of the run, has become more significant since 1989.

Terminal Area Management: Skagit spring chinook are managed for natural production. Sport and commercial salmon fisheries in the terminal area have been closed throughout the spring chinook management period in most years. One exception to this occurred in 1989, when a harvestable run was forecast to the Skagit, and limited sport and commercial fisheries were held during the spring chinook management period. In addition, since 1989, a test fishery has been conducted to obtain data on the age and hatchery/wild composition of the spring run. This fishery catches less than 50 spring chinook per year. At this time, there is no inseason update of run size for Skagit spring chinook.

1.4.3.1.2 Skagit Coho

Production: The Skagit system is managed for natural production of coho. Throughout the anadromous length of the system there are many pool/riffle areas, which are highly desirable for coho production. Spawner surveys and smolt studies have shown that coho spawn and rear throughout the watershed. The highest spawning densities generally occur in the upper basin, but the downstream sloughs and side channels are very important for rearing.

The Skagit also produces significant numbers of hatchery coho. The primary hatchery coho facility is WDF's Marblemount Hatchery on the Cascade River. Hatchery coho are also released from Baker Lake, in a cooperative project that involves WDF, Puget Power, and the Skagit System Cooperative, and from Swinomish Channel, in a cooperative project between WDF and the Skagit System Cooperative. Coho have also been held at the Skagit System Cooperative's Red Creek Hatchery, but this facility has been used primarily for steelhead. Release numbers vary from year to year. In recent years, smolt releases have typically been 150,000 to 300,000 from Marblemount, about 100,000 from Baker Lake, and 100,000 from Swinomish Channel. A net pen facility at Oak Harbor, on the west side of Skagit Bay, has also released about 30,000 smolts annually.

Terminal Area Management: Terminal area fisheries in the Skagit that catch coho include Treaty Indian fisheries, and non-Indian sport and commercial fisheries. There are three tribes that fish in the Skagit River: the Sauk-Suiattle, the Upper Skagit, and the Swinomish. Almost all the tribal fishing in Skagit Bay is done by the Swinomish Tribe.

Terminal area fisheries are planned annually in conjunction with the PFMC preseason planning process (see Section 1.2.1.3). Each year the Skagit System Cooperative and WDF have documented the agreements they have reached regarding the fishery management plan in a Memorandum of Understanding known as the Skagit MOU.

Treaty Indian terminal area fisheries are typically planned to satisfy requirements for ceremonial and subsistence fisheries, test fisheries and incidental coho catches; any coho remaining are allocated to coho directed fisheries.

Non-Indian fisheries in the Skagit terminal area include the Skagit Bay sport fishery, the Skagit River sport fishery, and the Skagit Bay commercial net fishery. The net fishery usually targets chum and pinks, with coho taken incidentally in these fisheries.

All the terminal area fisheries are managed to achieve a target escapement of Skagit wild coho, with the exception of the fisheries in Swinomish Channel. Because of a jetty built by the Corps of Engineers in the 1930s, almost all of the salmon migration to and from the river is diverted away from Swinomish Channel; consequently, catches in the Channel are assumed to be composed only of hatchery coho returning to a delayed-release site in the Channel. Swinomish Channel, therefore, is managed so as to maximize the harvest rate on these returning hatchery fish. An additional management objective of the preseason process is to balance the catch of treaty Indian and non-Indian fishers of coho returning to the Skagit River.

The conduct of the terminal fisheries may differ from the preseason plan depending on the results of an inseason update of coho run size. Since 1983, the inseason update has been done by analyzing the catch from a fishery conducted in early September. The terminal fisheries are then conducted according to preseason plans only if the updated run size is close to the preseason forecast. If the run size drops significantly, the terminal fisheries are further restricted according to steps defined in the preseason plan; in the rare event that the run size increases significantly, these fisheries may be similarly liberalized.

1.4.3.2 Skagit Spring Chinook Assessment

1.4.3.2.1 Distribution of Fishing Mortality

The distribution of adult equivalent fishing mortality of tagged Skagit spring chinook is given in Table 1.4 for brood years 1981 through 1987. On average, less than 1 percent of the mortality of this stock occurs in fisheries within the jurisdiction of the PFMC. Over 50 percent of the mortality occurs in Canada with the Puget Sound sport and net fisheries contributing an additional 42 percent.

1.4.3.2.2 Potential Escapement

The potential escapement of Skagit River spring chinook after Canadian and Alaskan fisheries exceeded the escapement goal (3,000) in two of the three years within the Overfishing Review Period (Fig. 1.8A). The potential escapement after Canadian and Alaskan fisheries ranged from 4,700 fish in 1988 and 1989 to 2,900 fish in 1990. The total potential escapement (no fishing) ranged from approximately 4,100 to 6,100 fish during the same time period.

With the exception of 1990, the potential escapement for the Skagit spring chinook stock has remained stable since 1986 (Fig. 1.8A). From 1986 to 1989, the potential escapement after Canadian and Alaskan fisheries ranged from 4,100 to 4,700 fish. The reduction of the potential escapement in 1990 to 2,900 fish was not related to failure of a specific brood. All broods contributing to the return in 1990 appeared to be reduced in abundance relative to previous years.

Table 1.4. Distribution of adult equivalent fishing mortality for the Skagit spring chinook stock. North net includes areas 4B, 5, 6C, 6, 7 and 7A.

BROOD	ALASKA ALL	CANADA ALL	PFMC SPT/TR	PUGET SOUND			
				TROLL	NORTH NET	OTHER NET	SPORT
1981	4	69	0	0	11	11	6
1982	0	209	2	0	0	7	40
1983	0	40	0	0	10	4	14
1984	1	59	0	0	0	37	20
1985	0	373	0	40	69	233	156
1986[1]	0	180	4	10	19	32	55
1987[2]	0	169	7	9	0	78	110
Total 1981-86	5	930	6	50	109	324	291
Percent	0.3%	54.2%	0.3%	2.9%	6.4%	18.9%	17.0%

[1] Incomplete brood; ages 2 through 4 included in analysis.
[2] Incomplete brood; ages 2 and 3 included in analysis.

1.4.3.2.3 Adult Equivalent Exploitation Rates

Adult equivalent brood exploitation rates have been estimated at greater than 70 percent for each brood tagged since 1981 (Fig. 1.8B). Estimated exploitation rates have ranged from 71 to 85 percent with an average of 78 percent (excluding the 1983 brood for which there were few recoveries). These estimates, however, may be biased high because they assume that all uncaught tagged hatchery fish (of the CWT indicator stock) enter the hatchery. Low flows during late summer and fall often prevent chinook from entering the hatchery, and the number of strays may have been significant in some years. In the years prior to 1989, in particular, the stray rate may have exceeded the return to the hatchery (P. Castle, WDF, pers. comm.) which would cause a significant overestimate of the exploitation rate.

1.4.3.3 Skagit Coho Assessment

1.4.3.3.1 Distribution of Fishing Mortality

The distribution of fishing mortality of tagged Skagit coho is given in Table 1.5 for fishing years 1988-1990. On average, approximately 7 percent of the mortality of this stock occurs in fisheries within the jurisdiction of the PFMC. About 60 percent of the mortality occurs in Canada with the Puget Sound sport and net fisheries contributing an additional 34 percent.

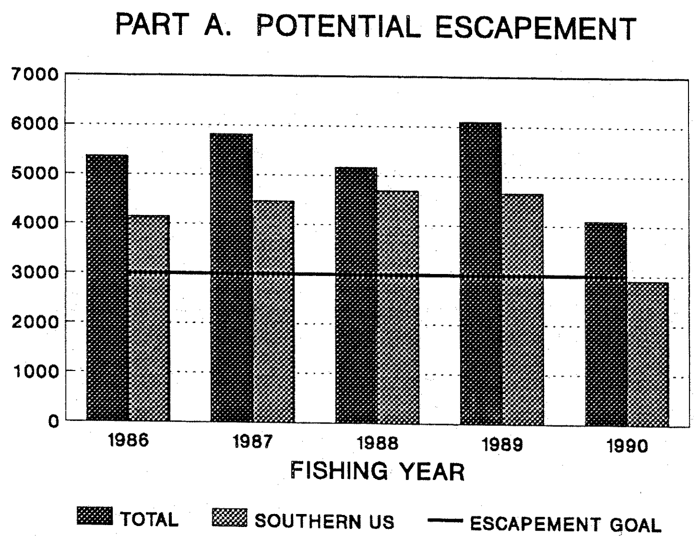
Table 1.5. Distribution of fishing mortality for Skagit River coho.

FISHERY	NUMBER			PERCENT			
	1988	1989	1990	1988	1989	1990	Mean
Canada	42,423	76,103	43,707	56.4	71.4	47.7	58.5
Ocean North of Cape Falcon/Buoy 10	3,037	5,028	6,343	4.0	4.7	6.9	5.2
Ocean South of Cape Falcon	3,058	534	26	4.1	0.5	0.0	1.5
Puget Sound Preterminal Sport	5,343	6,018	12,209	7.1	5.6	13.3	8.7
Puget Sound Terminal Sport	754	1,025	1,108	1.0	1.0	1.2	1.1
Puget Sound Troll	0	0	309	0.0	0.0	0.3	0.1
Puget Sound Preterminal Net (thru 9)	1,868	3,857	1,722	2.5	3.6	1.9	2.7
Skagit Terminal Net (8/fw)	9,363	7,420	9,305	12.4	7.0	10.2	9.9
Other Puget Sound Terminal Net	9,420	6,628	16,912	12.4	6.2	18.5	12.4
Total	75,266	106,613	91,641 1/				

1/ Does not include 37 recoveries in Alaskan fisheries.

4.3.3.2 Recruitment

Postseason estimates of recruitment for the Skagit natural coho stock exceeded the preseason expected recruitment in each year during the overfishing review period (Tables 1.6 through 1.8). The relative error of the preseason prediction (calculated by dividing the deviation by the postseason estimated value) was -11 percent in 1988, -37 percent in 1989, and -8 percent in 1990. The preseason and postseason estimates of natural mortality are based on an equal (assumed) value for the mortality, and deviations from the preseason prediction of natural mortality reflect only changes in the abundance of the stock or variation in the timing of the catch.



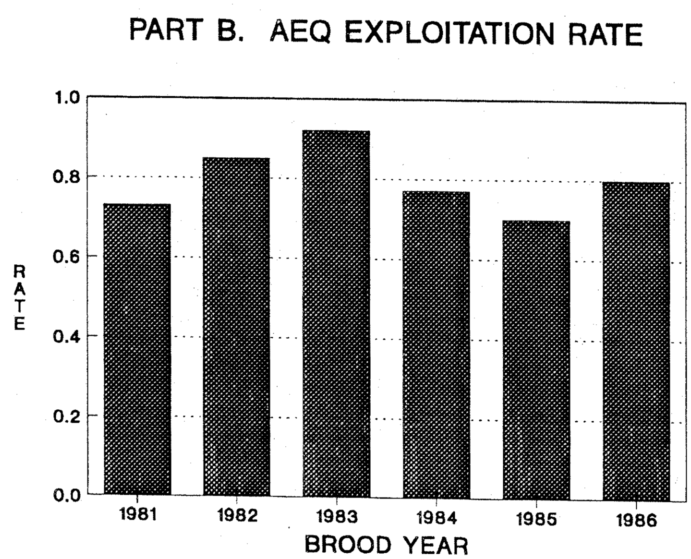


Figure 1.8. **Potential escapement and adult equivalent exploitation rates for the Skagit spring chinook stock.**

Recruitment in each year was sufficient to achieve the escapement objective in the absence of southern U.S. fisheries. Total recruitment was 127,562 in 1988, 166,214 in 1989, and 143,709 in 1990. Total mortality due to natural causes, nonlanded catch and Canadian fisheries was 75,690, 118,699 and 80,738 in the three respective years. Although mortality due to these factors reduced the total cohort size by 56 percent to 72 percent during these years, sufficient fish were available to U.S. fisheries to achieve the escapement objectives in each year.

1.4.3.3.3 Comparison of Pre- and Postseason Estimates of Catch and Exploitation Rates

Preseason predictions and postseason estimates of the total landed catch of all stocks, the landed and nonlanded mortality of the Skagit natural stocks, and mortality rates on the Skagit natural stock in the years 1988 through 1990 are presented in Tables 1.6 through 1.8. Preseason predictions of the total landed catch of all coho stocks were within 11 percent of the postseason estimate in each year. Preseason estimates of exploitation rates on the Skagit natural stock resulting from nonlanded catch mortality were underestimated by 9-15 percent. However, nonlanded catch is a relatively minor source of mortality for this stock and the effect of the error in the nonlanded catch exploitation rates was relatively small (400-800 fish). Estimates of the exploitation rates on the Skagit natural stock resulting from landed catch were also underestimated in each year. Relative errors ranged from -9 percent in 1988 to -12 percent in 1989. Errors of this magnitude could result in the observed deviations from the preseason expectation of escapement.

A more detailed comparison of preseason expectations and postseason estimates of total landed catch for all stocks, the landed catch of the Skagit natural stock, and exploitation rates for the Skagit natural coho stock are provided for the years 1988-1990 in Tables 1.9 through 1.11, respectively. Results are discussed by fishing year in the following sections.

1988: The pre-season prediction for the Canadian catch in the West Coast Vancouver Island troll (WCVI), Georgia Strait troll and sport fisheries (GS), and the Area 20 (Strait of Juan de Fuca) net fishery was underestimated by approximately 7 percent. The exploitation rate of the Skagit natural stock in these fisheries was also underpredicted by 2 percent. Within the Canadian fisheries, the preseason predictions for the exploitation rates were too low for the WCVI and GS fisheries. The underestimate for the exploitation rate in the GS fishery likely resulted from the predicted total catch for the fishery, which was underestimated by 37 percent. The same is not true, however, for the WCVI fisheries, where the exploitation rate was underpredicted by 11 percent, despite the total catch being overpredicted by 13 percent.

The preseason expectations for catch of coho salmon in the PFMC ocean fisheries (including Buoy 10) were within 1 percent of the postseason estimates. Excluding Buoy 10, the north of Cape Falcon ocean fisheries, which typically have the highest impact on the Skagit stock, harvested 1,200 more coho than planned preseason. In fisheries south of Cape Falcon, the preseason expectation of catch was underestimated by approximately 5 percent. The exploitation rate of the Skagit stock in the south of Cape Falcon fisheries was underestimated by 69 percent, and was as high as the exploitation rate in fisheries north of Cape Falcon.

The predicted catch in the preterminal and terminal Puget Sound fisheries combined was approximately 34 percent less than the postseason estimate of the catch. This was primarily due to greater than anticipated catches in the "Non-Skagit Terminal Net" category, which includes all terminal net fisheries other than those in Area 8 (Skagit Bay) and the Skagit River. Terminal run sizes for the

Nooksack/Samish and Stillaguamish/Snohomish regions were significantly greater than anticipated preseason. This increased the allowable terminal harvest in those areas, and at least in the case of the Stillaguamish/Snohomish region, increased the catch and exploitation rate on the Skagit stock. The catch in these non-Skagit terminal net fisheries was underestimated by 49 percent, and the exploitation rate was underpredicted by 48 percent.

1989: The predicted catch for the WCVI, GS, and Area 20 net fishery was overestimated by 5 percent. Within this group of fisheries, substantial variation existed between the preseason predictions and postseason estimates of catch. Preseason predictions of catch were too low for the WCVI and Area 20 net fishery. The catch in the WCVI fishery was underpredicted by 8 percent, and the exploitation rate on the Skagit stock was underpredicted by 34 percent. Catch of coho in the Area 20 net fishery was underpredicted by 32 percent, and the exploitation rate on Skagit natural coho was underpredicted by a similar amount (37 percent). The catch of the Skagit natural stock in the Georgia Strait sport and troll fisheries was underestimated, however the exploitation rate was overestimated by 42 percent.

The preseason prediction for catch in the PFMC ocean fisheries (including Buoy 10) was 7 percent greater than the postseason estimate. Much of the deviation is explained by the Buoy 10 fishery, where the catch was 118,100 coho less than the preseason expectation. The remaining PFMC ocean fisheries exceeded the preseason plan by 21,500 coho. The catch in the north of Cape Falcon troll fishery (treaty and non-Indian combined) exceeded the preseason expectation by 12,400 fish, and the preseason prediction for the exploitation rate on the Skagit stock was underestimated by 22 percent.

The predicted catch in the combined preterminal and terminal Puget sound fisheries was 10 percent greater than the estimated postseason catch. The majority of this deviation was due to non-Skagit terminal net fisheries, for which the predicted catch was 14 percent high. Although the predicted total catch in the non-Skagit terminal fisheries was overestimated, the predicted exploitation rate on the Skagit stock in these fisheries was underestimated by 9 percent.

1990: The preseason prediction of catch for the WCVI, GS, and Area 20 net fisheries was 5 percent greater than the postseason estimate. Predicted catches in the Area 20 and GS fisheries were approximately 20 percent greater the postseason estimates, while the preseason expectation for the WCVI fishery was underpredicted by 2 percent. The expected exploitation rate for the Skagit natural stock in the WCVI fishery was underestimated by 25 percent. The total catch in the Georgia Strait sport and troll fisheries was overestimated by 18 percent, however, the exploitation rate was overestimated by more than seven times.

Predicted catches in the PFMC ocean fisheries (including Buoy 10) exceeded the postseason estimates by 18 percent. Much of this deviation is explained by the Buoy 10 fishery, for which the estimated catch of 18,500 was substantially less than the anticipated catch of 140,000 coho. The predicted catch in the north of Cape Falcon troll fishery was underestimated by 3 percent, and the predicted exploitation rate for the Skagit natural stock was underestimated by 33 percent.

The predicted catch of all coho stocks in the combined preterminal and terminal Puget Sound fisheries was underpredicted by 19 percent. This is primarily due to underestimates of total catch in the Puget Sound preterminal sport and the non-Skagit terminal net fisheries. The expected catch in the Puget Sound preterminal sport fishery was underestimated by 29 percent, and the predicted exploitation rate was underestimated by 46 percent. The predicted exploitation rate on the Skagit natural stock was underestimated by 62 percent.

Table 1.6. Preseason predictions and postseason estimates of recruitment and mortality for the Skagit natural coho stock in 1988. Negative deviations indicate negative impact upon predicted escapement for stock.

RECRUITMENT OR SOURCE OF MORTALITY	TOTAL CATCH			SKAGIT NATURAL IMPACT			SKAGIT MORTALITY RATE[1]		
	EXPECTED	ESTIMATED	DEVIATION	EXPECTED	ESTIMATED	DEVIATION	EXPECTED	ESTIMATED	DEVIATION
RECRUITS	NA	NA	NA	113,088	127,562	14,474	NA	NA	NA
NATURAL MORTALITY	NA	NA	NA	25,183	29,375	-4,192	.223	.230	-3%
NONLANDED MORTALITY	NC	NC	NC	3,073	3,892	-819	.027	.031	-11%
LANDED MORTALITY	4,958,850	5,585,700	-11%	60,794	75,266	-14,472	.538	.590	-9%
OVERALL DEVIATION			-11%			-5,008			-7%

Table 1.7. Pre-season predictions and postseason estimates of recruitment and mortality for the Skagit natural coho stock in 1989. Negative deviations indicate negative impact upon predicted escapement for stock.

RECRUITMENT OR SOURCE OF MORTALITY	TOTAL CATCH			SKAGIT NATURAL IMPACT			SKAGIT MORTALITY RATE[1]		
	EXPECTED	ESTIMATED	DEVIATION	EXPECTED	ESTIMATED	DEVIATION	EXPECTED	ESTIMATED	DEVIATION
RECRUITS	NA	NA	NA	104,434	166,214	61,780	NA	NA	NA
NATURAL MORTALITY	NA	NA	NA	23,228	37,343	-14,115	.222	.225	-1%
NONLANDED MORTALITY	NC	NC	NC	2,806	5,253	-2,449	.027	.032	-15%
LANDED MORTALITY	5,523,500	5,196,700	6%	59,166	106,613	-47,447	.567	.641	-12%
OVERALL DEVIATION			6%			-2,229			-9%

[1] Rates computed as mortality divided by initial cohort.

Table 1.8. Pre-season predictions and postseason estimates of recruitment and mortality for the Skagit natural coho stock in 1990. Negative deviations indicate negative impact upon predicted escapement for stock.

RECRUITMENT OR SOURCE OF MORTALITY	TOTAL CATCH			SKAGIT NATURAL IMPACT			SKAGIT MORTALITY RATE[1]		
	EXPECTED	ESTIMATED	DEVIATION	EXPECTED	ESTIMATED	DEVIATION	EXPECTED	ESTIMATED	DEVIATION
RECRUITS	NA	NA	NA	132,291	143,709	11,418	NA	NA	NA
NATURAL MORTALITY	NA	NA	NA	29,507	32,760	-3,253	.223	.228	-2%
NONLANDED MORTALITY	NC	NC	NC	3,589	4,271	-682	.027	.030	-9%
LANDED MORTALITY	4,947,500	4,892,200	1%	75,821	91,678	-15,857	.573	.638	-10%
OVERALL DEVIATION			1%			-8,373			-8%

[1] Rates computed as mortality divided by initial cohort.

Table 1.9. Preseason predictions and postseason estimates of landed catch and exploitation rates for the Skagit natural coho stock in 1988. Negative deviations indicate negative impact upon predicted escapement of stock.

FISHERY	TOTAL CATCH			SKAGIT NATURAL IMPACT			SKAGIT NATURAL EXPLOITATION RATE[2]		
	EXPECTED	ESTIMATED	DEVIATION	EXPECTED	ESTIMATED	DEVIATION	EXPECTED	ESTIMATED	DEVIATION
CANADA									
WCVI Troll	1,800,000	1,595,600	13%	22,619	28,675	-6,056	.200	.225	-11%
GS Sport & Troll	843,900	1,341,200	-37%	6,562	11,164	-4,602	.058	.088	-34%
Area 20 Net	150,000	56,700	165%	6,898	1,719	5,179	.061	.013	353%
Total[1]	2,793,900	2,993,500	-7%	36,963	42,423	-5,459	.327	.333	-2%
U.S. OCEAN FISHERIES									
N. of Cape Falcon Troll	68,000	70,500	-4%	1,076	1,434	-358	.010	.011	-15%
N. of Cape Falcon Sport	300,000	242,100	24%	831	1,603	-772	.007	.013	-42%
S. of Falcon	983,100	1,039,900	-5%	850	3,058	-2,208	.008	.024	-69%
Total	1,351,100	1,352,500	0%	2,757	6,095	-3,338	.024	.048	-50%
PUGET SOUND FISHERIES									
Juan de Fuca Treaty Troll	1,000	600	67%	32	0	32	.000	.000	-
Preterminal Sport	192,600	187,600	3%	5,408	5,343	65	.048	.042	14%
Juan de Fuca Net	46,000	21,400	115%	2,381	448	1,933	.021	.004	500%
San Juan Net	80,000	83,900	-5%	2,062	1,296	766	.018	.010	80%
Area 6B/9 Net	9,400	7,900	19%	0	124	-124	.000	.001	-100%
Skagit Terminal Sport	10,200	8,500	20%	982	754	228	.009	.006	47%
Skagit Terminal Net	8,900	10,100	-12%	4,984	9,363	-3,455	.052	.073	-29%
Skagit Test Fishery	1,650	2,600	-37%	924					
Non-Skagit Terminal Net	464,100	917,100	-49%	4,301	9,420	-5,119	.038	.074	-48%
Total	813,850	1,239,700	-34%	21,075	26,748	-5,673	.186	.210	-11%
GRAND TOTAL	4,958,850	5,585,700	-11%	60,794	75,266	-14,472	.538	.590	-9%

[1] Natural impact and exploitation rate totals include all Canadian fisheries.
[2] Exploitation rates computed as landed catch divided by initial cohort.

Table 1.10. **Preseason predictions and postseason estimates of landed catch and exploitation rates for the Skagit natural coho stock in 1989. Negative deviations indicate negative impact upon predicted escapement for stock.**

FISHERY	TOTAL CATCH			SKAGIT NATURAL IMPACT			SKAGIT NATURAL EXPLOITATION RATE[2]		
	EXPECTED	ESTIMATED	DEVIATION	EXPECTED	ESTIMATED	DEVIATION	EXPECTED	ESTIMATED	DEVIATION
CANADA									
WCVI Troll	1,800,000	1,952,900	-8%	18,223	43,790	-25,567	.174	.263	-34%
GS Sport & Troll	964,600	570,600	69%	7,086	7,943	-857	.068	.048	42%
Area 20 Net	232,100	342,100	-32%	8,339	21,041	-12,702	.080	.127	-37%
Total[1]	2,996,600	2,865,600	5%	34,479	76,103	-41,624	.330	.458	-28%
U.S. OCEAN FISHERIES									
N. of Cape Falcon Troll	152,000	162,400	-6%	1,794	3,681	-1,887	.017	.022	-22%
N. of Cape Falcon Sport	445,000	329,000	35%	1,525	1,347	178	.015	.008	80%
S. of Falcon	845,900	854,900	-1%	753	534	219	.007	.003	124%
Total	1,442,900	1,346,300	7%	4,072	5,562	-1,490	.039	.033	17%
PUGET SOUND FISHERIES									
Juan de Fuca Treaty Troll	3,300	1,400	136%	92	0	92	.001	.000	-
Preterminal Sport	214,600	214,300	0%	4,617	6,018	-1,401	.044	.036	22%
Juan de Fuca Net	47,800	63,900	-25%	1,898	1,936	-38	.018	.012	56%
San Juan Net	140,200	114,300	23%	3,688	1,921	1,767	.035	.012	206%
Area 6B/9 Net	4,000	6,000	-33%	0	0	0	.000	.000	-
Skagit Terminal Sport	10,500	6,400	64%	366	1,025	-659	.004	.006	-43%
Skagit Terminal Net	11,800	8,000	48%	5,330	7,420	-1,274	.059	.045	32%
Skagit Test Fishery	1,800	1,000	80%	816					
Non-Skagit Terminal Net	650,000	569,500	14%	3,808	6,628	-2,820	.036	.040	-9%
Total	1,084,000	984,800	10%	20,615	24,948	-4,333	.197	.150	32%
GRAND TOTAL	5,523,500	5,196,700	6%	59,166	106,613	-47,447	.567	.641	-12%

[1] Natural impact and exploitation rate totals include all Canadian fisheries. [2] Negative deviations refer to effect on escapement.
[2] Exploitation rates computed as landed catch divided by initial cohort.

Table 1.11. **Preseason predictions and postseason estimates of landed catch and exploitation rates for the Skagit natural coho stock in 1990. Negative deviations indicate negative impact upon predicted escapement for stock.**

FISHERY	TOTAL CATCH			SKAGIT NATURAL IMPACT			SKAGIT NATURAL EXPLOITATION RATE[2]		
	EXPECTED	ESTIMATED	DEVIATION	EXPECTED	ESTIMATED	DEVIATION	EXPECTED	ESTIMATED	DEVIATION
CANADA									
WCVI Troll	1,800,000	1,844,900	-2%	24,779	35,745	-10,966	.187	.249	-25%
GS Sport & Troll	912,100	773,600	18%	8,865	1,093	7,772	.067	.008	781%
Area 20 Net	175,000	142,900	22%	8,087	6,480	1,607	.061	.045	36%
Total[1]	2,887,100	2,761,400	5%	42,761	43,707	-946	.323	.304	6%
U.S. OCEAN FISHERIES									
N. of Cape Falcon Troll	195,000	201,100	-3%	2,930	4,752	-1,822	.022	.033	-33%
N. of Cape Falcon Sport	405,000	279,200	45%	2,326	1,591	735	.018	.011	59%
S. of Falcon	475,900	435,300	9%	646	26	620	.005	.000	2599%
Total	1,075,900	915,600	18%	5,903	6,369	-466	.045	.044	1%
PUGET SOUND FISHERIES									
Juan de Fuca Treaty Troll	2,900	1,900	53%	101	309	-208	.001	.002	-64%
Preterminal Sport	221,800	313,400	-29%	6,032	12,209	-6,177	.046	.085	-46%
Juan de Fuca Net	52,600	31,000	70%	2,592	852	1,740	.020	.006	230%
San Juan Net	115,700	104,900	10%	3,275	870	2,405	.025	.006	309%
Area 6B/9 Net	0	9,700	-100%	0	0	0	.000	.000	-
Skagit Terminal Sport	10,100	7,500	35%	907	1,108	-201	.007	.008	-11%
Skagit Terminal Net	12,200	9,658	26%	7,231	9,305	-948	.063	.065	-2%
Skagit Test Fishery	1,900	1,600	19%	1,126					
Non-Skagit Terminal Net	567,300	735,500	-23%	5,893	16,912	-11,019	.045	.118	-62%
Total	984,5000	1,215,200	-19%	27,158	41,565	-14,407	.205	.289	-29%
GRAND TOTAL	4,947,500	4,892,200	1%	75,821	91,678	-15,857	.572	.638	-10%

[1] Natural impact and exploitation rate totals include all Canadian fisheries. NA - not available.
[2] Exploitation rates computed as landed catch divided by initial cohort.

1.4.3.3.4 Terminal Area Net Fishery Catches

1988 Management: The 1988 Skagit MOU provided for a target Treaty Indian terminal area catch of 8,400, with 2 to 3 days directed fishing per tribe if the inseason projection of escapement was above 22,000. The run size update indicated that the escapement would be 23,953 thus meeting the criterion. Accordingly, each tribe conducted a 1-day opening each of the last 2 weeks of September. The target catch was about 4,500 coho. The first two Swinomish openings, and the first Upper Skagit/Sauk-Suiattle opening, caught about 1,000 coho/day. The second Upper Skagit/Sauk-Suiattle opening, which was also projected to catch about 1,000 coho (preliminary inseason data showed about 1,400 remaining for directed fisheries), instead caught about 3,400.

In response, the Upper Skagit Tribe instituted additional gear and area restrictions on their chum fishery, and delayed their chum opening, to reduce their incidental coho catch. This resulted in a reduction in the incidental coho catch from the 3,150 that was projected to 1,863. The total treaty Indian terminal coho catch (excluding Swinomish Channel, which is a hatchery return area) was 9,606, compared to a target of 8,400. The non-Indian catch, which was all taken incidental to chum fisheries, was 510, compared to an expected catch of 480 (Table 1.12). The catch of wild coho in terminal area fisheries was 3,455 higher than anticipated preseason.

Table 1.12. Summary of expected and observed catches in Skagit terminal area net fisheries.

FISHERY	1988		1989		1990	
	EXPECTED	OBSERVED	EXPECTED	OBSERVED	EXPECTED	OB-SERVED
Non-Indian Catch	480	510	1,602	2,090	471	210
Treaty Indian Catches						
Pink/ISU	750	810	6,627	4,526	717	926
Coho Directed	4,500	6,923	0	0	7,600	7,577
Chum/Stlhd	3,150	1,863	3,615	1,368	3,399	945
Other Tribes	0	10	0	11	0	0
Total	8,400	9,606	10,242	5,905	11,716	9,448
Commercial Total	8,880	10,126	11,844	8,006	12,187	9,658
Test Fishery	1,650	2,620	1,800	1,003	1,900	1,628
Swinomish Channel /1	---	1,962	---	1,370	---	2,329

1/ Swinomish Channel catches are hatchery returns, and were not included in preseason projections.

In comparing the preseason forecast and the inseason update to the run size estimated postseason, the terminal update was closer to the postseason estimate than the preseason forecast was, but it was still some 11,500 higher than the postseason number (Table 1.13). However, almost all of that overestimate was for the hatchery component of the run -- the updated wild run size, 29,606, was only 4 percent greater than the postseason estimate of 28,370.

Table 1.13. Comparison of Skagit preseason forecast (PSF), inseason estimate (ISU), and postseason estimate (POST) of total terminal run (hatchery plus natural), natural run, and hatchery run.

YEAR	TOTAL TERMINAL RUN			NATURAL RUN			HATCHERY RUN		
	PSF	ISU	POST	PSF	ISU	POST	PSF	ISU	POST
1988	57,100	55,234	43,719	38,000	29,606	28,370	19,100	25,625	15,349
1989	58,540	44,577	34,206	33,074	20,247	24,422	25,466	24,330	9,784
1990	59,592	59,258	35,233	32,294	32,113	24,306	27,298	27,145	10,927

1989 Management: The 1989 Skagit MOU provided that there would be no directed coho fisheries in the Skagit terminal area unless the inseason update indicated that wild escapement would be above 30,000. The inseason update (which was done during the pink fishery) projected the escapement at 14,900, so no additional fisheries were held.

The total terminal commercial catch, excluding Swinomish Channel, was 8,006, compared to a preseason prediction of 11,844, or about 3,800 less than predicted (Table 1.12). The Treaty Indian catch was 5,905, compared to a prediction of 10,242; the non-Indian catch was 2,090, compared to a prediction of 1,602. The catch of wild coho in terminal area fisheries was 1,274 higher than anticipated preseason.

The inseason update of total terminal run size was about 10,000 higher than the postseason estimate, but was still much more accurate than the preseason forecast (Table 1.13). As noted above, this overestimate had no effect on management actions -- the updated run size was so low that management actions would have been the same even without this overestimate. As in 1988, the overestimate was primarily due to overestimating the hatchery component; the update of wild run size was actually 17 percent lower than the postseason estimate.

1990 Management: The 1990 Skagit MOU provided for a target Treaty Indian catch of 11,700. This catch would be reduced if the inseason projection of escapement was below 21,400. The update projected an escapement of 24,200, so the target catch number was not changed, and treaty Indian directed fisheries were conducted.

The directed coho catch, 7,577, was about the same as the preseason projected directed catch (7,600). The treaty Indian incidental catch during chum and steelhead fisheries, however, was only 945, compared to a preseason projection of 3,399; this resulted in a total treaty Indian terminal catch (excluding Swinomish Channel) of 9,448, compared to a target of 11,700 (Table 1.12).

The non-Indian terminal catch is estimated at 210 compared to a preseason projection of 471. The catch of wild coho in terminal area fisheries was 948 higher than anticipated preseason.

The inseason update was essentially the same as the preseason forecast. Both the hatchery and wild components were significantly overestimated. However, the greatest overestimate was again on the hatchery component (Table 1.13).

There is a general problem in that neither the preseason forecast nor the update are very accurate. Although the updates were closer to the actual run size, they too consistently overestimated the Skagit terminal run size in each of the last 3 years (Table 1.13). This overestimate did not change management in 1989, but it did allow fisheries that might otherwise not have been conducted in 1988 and 1990. These directed fisheries caught an estimated 4,500 wild coho in 1988, and 5,200 wild coho in 1990. The underescapements in 1988 and 1990 were 5,000 and 8,400 wild coho, respectively. Even if managers had perfect knowledge of the terminal run size and managed accordingly, the stock still would not have met its escapement objective in any of the three years, although the deviation would have been small in 1988.

1.4.3.3.5 Harvest Rate Index

The harvest rate index (catch divided by catch plus escapement) for Skagit coho was 66 percent in 1988, 70 percent in 1989, and 73 percent in 1990.

1.4.4 HOOD CANAL

1.4.4.1 Introduction

Hood Canal is a major arm of Puget Sound located in northwestern Washington (Fig. 9). It is a 61 mile long fishhook shaped glacial fjord that is bordered on the west by the steep and heavily forested Olympic Mountains and on the east by the low rolling hills of the Kitsap Peninsula. The Hood Canal watershed drains an area of approximately 900 square miles.

1.4.4.1.1 Production

Natural coho production in Hood Canal is derived from many small streams and river systems that empty into the Hood Canal basin. There are approximately 330 miles of accessible habitat with an estimated production potential of approximately one million smolts annually (Zillges 1977).

The most productive areas for coho are located on the east side of Hood Canal on the Kitsap Peninsula. The major streams in this area include the Dewatto, Tahuya and Union rivers and a large number of smaller creeks. These streams are characterized by long stretches of low gradient habitat that is ideally suited for coho production.

The Skokomish River enters Hood Canal at its southern most point and is the largest river in the area. It divides into the North and South forks at RM 9. There are 8.3 miles of additional habitat on the North Fork below a hydroelectric dam. The dam blocks access to the upper section of the North Fork and affects production in the lower river by diverting the majority of flow to a pipe line that drains directly to Hood Canal. The South Fork is inaccessible to salmon above RM 21.3.

The principal streams on the west side of Hood Canal include the Hamma Hamma, Duckabush and Dosewallips rivers. These streams and the smaller independent streams between, originate in the Olympic Mountains and are characterized by steep gradient and short reaches of accessible habitat.

The Quilcene and Port Gamble basins do not contribute significantly to natural coho production. Hatchery facilities are located in these regions and both are managed for hatchery production.

There are five coho production facilities in Hood Canal. Delayed release net pen programs are located on both Port Gamble (9A) and Quilcene bays (12A). The Quilcene National Fish Hatchery (QNFH) is at RM 2.8 on the Quilcene River. The Hoodsport Hatchery is located in Hoodsport, Washington on Finch Creek on the west side of Hood Canal. The George Adams Hatchery is on Purdy Creek, a tributary entering the Skokomish River at RM 4.1.

Current production at the Quilcene and Port Gamble net pen facilities are set at 360,000 and 400,000 smolts annually. The QNFH is programmed for release of 250,000 smolts but frequently produces substantially more because of escapement shortfalls of spring chinook and the resulting availability of production space. The Hoodsport Hatchery releases 40,000 smolts of an early returning stock. The intent is to maintain a broodstock to support the production release of 100,000 smolts at the George Adams Hatchery on the Skokomish River. This is an evaluation program designed to determine if the early stock can be used to increase production and management flexibility. In addition to early stock production, 300,000 smolts are released at George Adams from onstation production. The release at George Adams is limited because the Skokomish River is managed for natural stocks. In most years, there is substantial overescapement at the hatchery due to reduced harvest rates for natural stocks.

1.4.4.1.2 Terminal Area Management

The management of fisheries in Hood Canal has changed substantially in recent years. For many years, Hood Canal was managed as a sport fishing preserve thus excluding commercial coho fisheries. This changed during the mid 70s in response to the Federal Court's recognition of Treaty Indian fishing rights. Court sanctioned fisheries were first initiated in south Hood Canal in 1974 with effort expanding into north Hood Canal over the following three or four years. The non-Indian commercial fleet participated in these fisheries as well.

Hood Canal is subdivided into several management areas (Fig. 1.9). The main stem of Hood Canal (areas 12, 12B, 12C and 12D) was managed for natural production from the outset of the commercial fishery. The Skokomish River was initially managed for hatchery production but was changed to natural production in 1979. The existing management scenario was fully implemented in 1980. Coho in the main stem of Hood Canal and the Skokomish River are now managed for natural production. Port Gamble and Quilcene bays (areas 9A and 12A) are managed for hatchery production. A small portion of Area 9 is managed in conjunction with 9A. This is referred to as the on-reservation Area 9 fishery and consists of approximately 1,000 yd of beach and 10 set net sites on the north beach adjacent to the entrance of Port Gamble Bay.

The Hood Canal natural stock is managed for a fixed escapement goal of 19,100 adult spawners. The escapement objective was reduced in 1988 and 1991 when forecasts were quite low and it became apparent that the full goal could not be met without reducing fisheries to a level that was deemed unacceptable.

Harvest rates in the terminal area are set using preseason forecasts of abundance and estimates of catch in fisheries outside of Hood Canal including the U.S. and Canadian ocean fisheries, the Puget Sound sport fishery and preterminal net fisheries. This accounting provides an estimate of terminal run size that is used to set the terminal harvest rate.

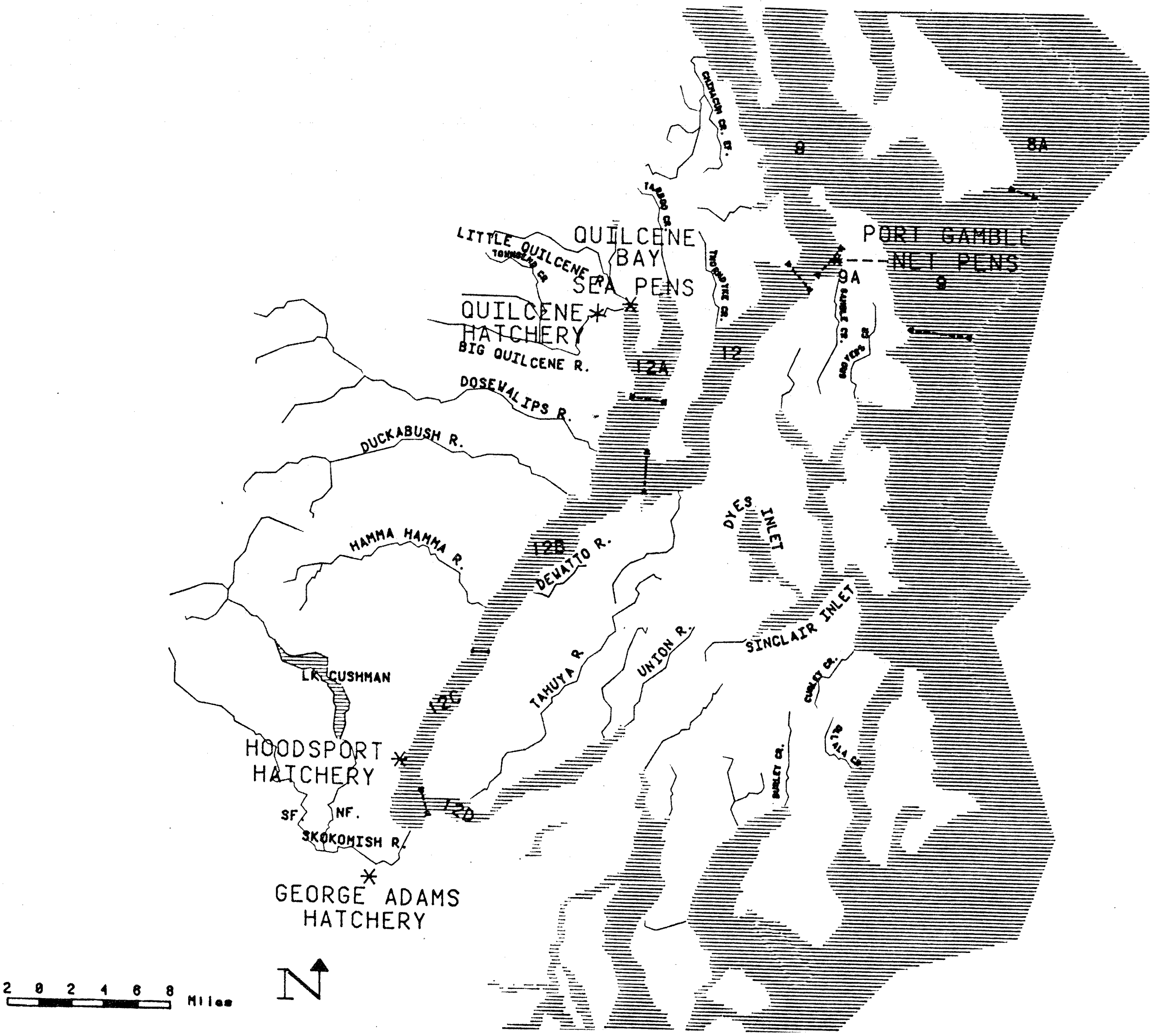


Figure 1.9. Detailed map of Hood Canal.

Terminal catch is divided between directed and incidental harvest. Once the anticipated incidental catches are estimated, the remainder is available for directed harvest. Incidental catches are those taken during fisheries directed at other species including chinook and particularly chum salmon. The definition of a directed fishery is one that occurs within the management period set for that species. Management periods are set for each species and area based on time of entry with the intent of directing management efforts at the central 80 percent of the run.

Treaty Indian and non-Indian allocations are determined through a separate accounting process. The respective directed fisheries are managed through time and area restrictions to harvest the available allocations.

In past years, the terminal run size was "updated" by relating inseason catch per unit effort (CPUE) data to the historical record of CPUE and terminal run size for fisheries in similar areas and times. The update is used to modify preseason estimates of terminal run size and the available harvest and allocations are then recalculated. Our ability to rely on these updates has diminished in recent years because of generally poor returns.

Harvest rates in Area 12A are determined from the escapement goal for the QNFH, although in practice this has not been very restrictive on harvest. Brood stock for the 9A production comes from outside the system so there is no escapement goal. As a result, both systems are subject to harvest rates in excess of 90 percent. It is currently assumed that natural stocks do not stray into these embayments and the impact of these fisheries on natural stocks is minimal. This is an assumptions that warrants further review.

There is some limited natural production in areas 9A and 12A streams. However, given the history of hatchery management and resulting high harvest rates, most of the natural production in these areas probably comes from hatchery strays.

The Hood Canal coho escapement goal of 19,100 includes a natural production component for areas 9A and 12A based on measures of available habitat. Since these areas are not managed for natural production, it would be appropriate to adjust the escapement goal so that it includes only those areas that are managed for natural production. However, it would also be necessary to make concurrent adjustments in the forecast methodology since it now includes a component of natural production for those areas.

1.4.4.2 Hood Canal Coho Assessment

1.4.4.2.1 Distribution of Mortality

The distribution of fishing mortality for tagged Hood Canal coho is given in Table 1.14 for fishing years 1988-1990. On average, approximately 6 percent of the mortality occurs in fisheries within the jurisdiction of the PFMC. About 41 percent of the mortality occurs in Canada, with the Puget Sound sport and net fisheries contributing an additional 53 percent.

Table 1.14. Distribution of fishing mortality for Hood Canal coho.

FISHERY	NUMBER			PERCENT			
	1988	1989	1990	1988	1989	1990	Mean
Canada	9119	19357	19815	34.7	49.0	39.1	40.9
Ocean North of Cape Falcon/Buoy 10	674	1665	2717	2.6	4.2	5.4	4.1
Ocean South of Cape Falcon	1914	0	0	7.3	0.0	0.0	2.4
Puget Sound Preterminal Sport	3267	2395	6260	12.4	6.1	12.4	10.3
Puget Sound Terminal Sport	51	527	98	0.2	1.3	0.2	0.6
Puget Sound Troll	0	157	24	0.0	0.4	0.1	0.2
Puget Sound Preterminal Net (thru 9)	844	2866	2504	3.2	7.3	4.9	5.1
Hood Canal Terminal Net	3537	8706	6913	13.4	22.0	13.6	16.3
Other Puget Sound Terminal Net	6892	3827	12355	26.2	9.7	24.4	20.1
Total	26298	39500	50686				

4.4.2.2 Recruitment

Recruitment to southern U.S. fisheries was sufficient in each of the years during the overfishing review period to achieve the escapement objective. Total recruitment was approximately 51,400 in 1988, 73,900 in 1989, and 77,400 in 1990 (Tables 1.15-1.17). The landed catch in southern U.S. fisheries plus escapement was 28,789 in 1988 (escapement objective of 14,700), 35,453 in 1989 (escapement objective of 19,100), and 37,671 in 1990 (escapement objective of 19,100). Since recruitment was sufficient to achieve the escapement objective in each year, subsequent analyses attempted to determine the reason for the shortfall in the escapement.

The preseason forecasts for the Hood Canal natural run overestimated the abundance in each year of the overfishing period (Tables 1.15-1.17). The relative error (calculated by dividing the deviation by the postseason estimated value) of the estimate was 1 percent in 1988, 43 percent in 1989, and 59 percent in 1990.

Table 1.15. Preseason predictions and postseason estimates of recruitment and mortality for the Hood Canal natural coho stock in 1988. Negative deviations indicate negative impact upon predicted escapement of stock.

RECRUITMENT OR SOURCE OF MORTALITY	TOTAL CATCH			HOOD CANAL NATURAL IMPACT			HOOD CANAL MORTALITY RATE[1]		
	EXPECTED	ESTIMATED	DEVIATION	EXPECTED	ESTIMATED	DEVIATION	EXPECTED	ESTIMATED	DEVIATION
RECRUITS	NA	NA	NA	51,870	51,430	-440	NA	NA	NA
NATURAL MORTALITY	NA	NA	NA	11,953	12,541	-588	.230	.244	-5%
NONLANDED MORTALITY	NC	NC	NC	1,277	978	299	.025	.019	29%
LANDED MORTALITY	4,978,100	5,583,300	-11%	23,927	26,298	2,371	.461	.511	-10%
OVERALL DEVIATION			-11%			-3,100			-7%

Table 1.16. Preseason predictions and postseason estimates of recruitment and mortality for the Hood Canal natural coho stock in 1989. Negative deviations indicate negative impact upon predicted escapement of stock.

RECRUITMENT OR SOURCE OF MORTALITY	TOTAL CATCH			HOOD CANAL NATURAL IMPACT			HOOD CANAL MORTALITY RATE[1]		
	EXPECTED	ESTIMATED	DEVIATION	EXPECTED	ESTIMATED	DEVIATION	EXPECTED	ESTIMATED	DEVIATION
RECRUITS	NA	NA	NA	105,659	73,901	-31,758	NA	NA	NA
NATURAL MORTALITY	NA	NA	NA	22,039	17,594	4,445	.209	.238	-12%
NONLANDED MORTALITY	NC	NC	NC	2,715	1,499	1,216	.026	.020	27%
LANDED MORTALITY	5,536,900	5,213,200	6%	61,805	39,500	22,305	.585	.534	9%
OVERALL DEVIATION			6%			-3,792			3%

[1] Rates computed as mortality divided by initial cohort.

Table 1.17. Preseason predictions and postseason estimates of recruitment and mortality for the Hood Canal natural coho stock in 1990. Negative deviations indicate negative impact upon predicted escapement of stock.

RECRUITMENT OR SOURCE OF MORTALITY	TOTAL CATCH			HOOD CANAL NATURAL IMPACT			HOOD CANAL MORTALITY RATE[1]		
	EXPECTED	ESTIMATED	DEVIATION	EXPECTED	ESTIMATED	DEVIATION	EXPECTED	ESTIMATED	DEVIATION
RECRUITS	NA	NA	NA	123,309	77,361	-45,948	NA	NA	NA
NATURAL MORTALITY	NA	NA	NA	24,910	17,728	7,182	.202	.229	-12%
NONLANDED MORTALITY	NC	NC	NC	3,224	2,147	1,077	.026	.028	-6%
LANDED MORTALITY	4,968,200	4,905,800	1%	76,075	50,686	25,389	.617	.655	-6%
TOTAL			1%			-12,300			-7%

[1] Rates computed as mortality divided by initial cohort.

1.4.4.2.3 Comparison of Pre- and Postseason Estimates of Catch and Exploitation Rates

Preseason predictions and postseason estimates of the total landed catch of all stocks, the landed and nonlanded catch mortality of the Hood Canal natural stock, and natural mortality of the Hood Canal natural stock in the years 1988 through 1990 are presented in Tables 1.15 through 1.17. Preseason predictions of the total landed catch and the resultant exploitation rates were within 11 percent of the postseason estimate in each of the years. Relative errors in the predicted exploitation rates for landed catch of the Hood Canal natural stock ranged from -10 percent to 9 percent. The relative error of the preseason estimates of exploitation rates on the Hood Canal stock resulting from nonlanded catch mortality ranged from -6 percent to 29 percent.

A more detailed comparison of preseason expectations and postseason estimates of total landed catch for all stocks, the landed catch of the Hood Canal natural stock, and exploitation rates for the Hood Canal natural coho stock are provided for the years 1988-1990 in Tables 1.18 through 1.20, respectively. Results are discussed by fishing year in the following sections.

1988: The preseason prediction for catch in the WCVI troll, GS sport and troll, and Area 20 net was underestimated by 7 percent. This primarily resulted from a predicted catch for the GS sport and troll fishery which was underestimated by 37 percent. The error in the GS catch prediction had little effect on the predicted mortality of the Hood Canal stock since the harvest of the Hood Canal stock in these fisheries in 1988 was minimal. Preseason predictions of exploitation rates in the WCVI troll and Area 20 net fishery were overestimated by 50 and 192 percent, respectively. In part, this may be attributed to preseason predictions for catch which were overestimated by 13 percent in the WCVI troll fishery, and 165 percent for the area 20 net fishery.

Preseason predictions of catch in PFMC fisheries were quite accurate in 1988, with a relative error over all fisheries of less than 1 percent. The predicted exploitation rate for PFMC fisheries was underestimated by 27 percent. This resulted primarily from an underprediction in the exploitation rate for the south of Cape Falcon fisheries. Predicted exploitation rates in the south of Cape Falcon fisheries were 60 percent less than the postseason estimate.

The preseason prediction for the catch in all Puget Sound fisheries combined was 33 percent less than the actual catch. Predicted exploitation rates in Puget Sound fisheries in total were also underpredicted by 54 percent. Much of the deviation may be attributed to the non-Hood Canal terminal net fisheries, for which the catch was underpredicted 50 percent. The exploitation rate in these fisheries was underpredicted by 79 percent. Exploitation rates were also underestimated for the Puget Sound preterminal sport fisheries and for the Hood Canal terminal net fishery by 40 and 51 percent, respectively.

1989: The preseason predictions in 1989 were relatively good for the total Canadian catch and exploitation rate. The preseason prediction for the catch in Canadian fisheries was within 5 percent of the actual catch, and the predicted exploitation rate only 8 percent less than the postseason estimate. Within the Canadian fisheries, the relative error of the predicted exploitation rate was greatest for the GS sport and troll fishery. In that fishery, the preseason expectation of the exploitation rate was overestimated by 98 percent.

The preseason prediction for the catch in the PFMC fisheries was within 7 percent of the actual catch. Preseason predictions of exploitation rates were higher than the postseason estimates in each of the PFMC fisheries. The predicted exploitation rate on the Hood Canal natural stock for all PFMC fisheries was overestimated by 145 percent.

The preseason expectation of catch in all Puget Sound fisheries combined was overestimated by 10 percent. The greatest relative error was for the Hood Canal terminal sport and net fisheries, for which the preseason predictions were overestimated by 457 percent and 100 percent, respectively. Preseason estimates of exploitation rates in these fisheries were also high. The preseason predictions for catch were too low for the Area 6B/9 net fishery and for the Juan de Fuca net fishery. The preseason estimate for the catch in the Juan de Fuca net fishery was low by 25 percent, and the predicted exploitation rate was 52 percent less than the postseason estimate. In the Area 6B/9 net fishery, the preseason predictions for catch and the exploitation rate were low by 33 percent and 80 percent, respectively. The exploitation rate in the non-Hood Canal terminal net fisheries was underestimated by 44%.

1990: Preseason predictions for the catch and exploitation rates in the aggregate of Canadian fisheries were within 5 percent of the postseason estimates. For the WCVI troll fishery, in which the majority of the fishing mortality for the Hood Canal stock occurs, the exploitation rate prediction was overestimated by 2 percent, even though the total catch in this fishery was underestimated by 2 percent. Preseason predictions for the catch and exploitation rates in the other major Canadian fisheries were overestimated.

Predicted catches in the PFMC fisheries and Buoy 10 were overestimated by 18 percent. The greatest relative error in the predicted catch for PFMC fisheries occurred in the north of Cape Falcon sport fishery/Buoy 10. The predicted catch for these fisheries was overestimated by 45 percent. Much of this deviation is explained by the Buoy 10 fishery, in which a catch of 140,000 coho was anticipated but only 18,500 were caught. The predicted exploitation rate for this fishery was 120 percent higher than the postseason estimate. Preseason predictions of exploitation rates in the north of Cape Falcon troll and south of Cape Falcon fisheries were also overestimated.

The predicted catch in all Puget Sound fisheries combined was underestimated by 18 percent. This is primarily due to underestimates of the total catch in the Puget Sound preterminal sport fishery, 6B/9 net fishery, and the non-Hood Canal terminal net fisheries. The catch in the Puget Sound preterminal sport fisheries was underestimated by 29 percent, and the natural Hood Canal exploitation rate was underestimated by 51 percent. Both the catch and exploitation rate in the 6B/9 net fishery were underestimated by 100 percent. The catch in the non-Hood Canal terminal net fisheries was underestimated by 27 percent. The preseason exploitation rate for this fishery was also underpredicted by 86 percent. Both the predicted catch and the exploitation rate used during preseason planning for the Hood Canal terminal net fishery were overestimated by 101 percent.

Table 1.18. Preseason predictions and postseason estimates of landed catch and exploitation rates for the Hood Canal natural coho stock in 1988. Negative deviations indicate negative impact upon predicted escapement of stock.

FISHERY	TOTAL CATCH			HC NATURAL IMPACT			HC NATURAL EXPLOITATION RATE[2]		
	EXPECTED	ESTIMATED	DEVIATION	EXPECTED	ESTIMATED	DEVIATION	EXPECTED	ESTIMATED	DEVIATION
CANADA									
WCVI Troll	1,800,000	1,595,600	13%	12,712	8,392	4,320	.245	.163	50%
GS Sport & Troll	843,900	1,341,200	-37%	479	0	479	.009	.000	-
Area 20 Net	150,000	56,700	165%	1,906	648	1,258	.037	.013	192%
Total[1]	2,793,900	2,993,500	-7%	15,239	9,119	6,120	.294	.177	66%
U.S. OCEAN FISHERIES									
N. of Cape Falcon Troll	68,000	70,500	-4%	711	266	445	.014	.005	165%
N. of Cape Falcon Sport	300,000	242,100	24%	443	408	35	.009	.008	8%
S. of Falcon	983,100	1,039,900	-5%	763	1,914	-1,151	.015	.037	-60%
Total	1,351,100	1,352,500	0%	1,917	2,588	-671	.037	.050	-27%
PUGET SOUND FISHERIES									
Juan de Fuca Treaty Troll	1,000	600	67%	12	0	12	.000	.000	-
Preterminal Sport	200,600	194,400	3%	1,982	3,267	-1,285	.038	.064	-40%
Juan de Fuca Net	46,000	21,400	115%	443	240	203	.009	.005	83%
San Juan Net	80,000	83,900	-5%	270	284	-14	.005	.006	-6%
Area 6B/9 Net	9,400	7,900	19%	629	320	309	.012	.006	95%
Hood Canal Terminal Sport	1,200	1,200	0%	215	51	164	.004	.001	317%
Hood Canal Terminal Net	32,600	12,300	165%	1,318	3,537	-1,803	.033	.069	-51%
Hood Canal Test Fishery	1,800	1,600	13%	416					
Non-H. Canal Terminal Net	460,500	914,000	-50%	1,488	6,892	-5,404	.029	.134	-79%
Total	833,100	1,237,300	-33%	6,771	14,591	-7,820	.131	.284	-54%
GRAND TOTAL	4,978,100	5,583,300	-11%	23,927	26,298	-2,371	.461	.511	-10%

[1] Natural impact and exploitation rate totals include all Canadian fisheries.
[2] Exploitation rates are computed as landed catch divided by initial cohort.

Table 1.19. Preseason predictions and postseason estimates of landed catch and exploitation rates for the Hood Canal natural coho stock in 1989. Negative deviations indicate negative impact upon predicted escapement of stock.

FISHERY	TOTAL CATCH			HC NATURAL IMPACT			HC NATURAL EXPLOITATION RATE[2]		
	EXPECTED	ESTIMATED	DEVIATION	EXPECTED	ESTIMATED	DEVIATION	EXPECTED	ESTIMATED	DEVIATION
CANADA									
WCVI Troll	1,800,000	1,952,900	-8%	23,066	13,939	9,127	.218	.189	16%
GS Sport & Troll	964,600	570,600	69%	1,189	420	769	.011	.006	98%
Area 20 Net	232,100	342,100	-32%	5,216	4,340	876	.049	.059	-16%
Total[1]	2,996,600	2,865,600	5%	29,764	19,357	10,407	.282	.262	8%
U.S. OCEAN FISHERIES									
N. of Cape Falcon Troll	152,000	162,400	-6%	2,602	1,051	1,551	.025	.014	73%
N. of Cape Falcon Sport	445,000	329,000	35%	1,811	614	1,197	.017	.008	106%
S. of Falcon	845,900	854,900	-1%	1,421	0	1,421	.013	.000	-
Total	1,442,900	1,346,300	7%	5,834	1,665	4,169	.055	.023	145%
PUGET SOUND FISHERIES									
Juan de Fuca Treaty Troll	3,300	1,400	136%	111	157	-46	.001	.002	-50%
Preterminal Sport	221,600	220,400	1%	3,953	2,395	1,558	.037	.032	15%
Juan de Fuca Net	47,800	63,900	-25%	926	1,349	-423	.009	.018	-52%
San Juan Net	140,200	114,300	23%	1,329	125	1,204	.013	.002	643%
Area 6B/9 Net	4,000	6,000	-33%	407	1,392	-985	.004	.019	-80%
Hood Canal Terminal Sport	3,900	700	457%	966	527	439	.009	.007	28%
Hood Canal Terminal Net	69,900	35,000	100%	15,465	8,706	6,759	.146	.118	24%
Hood Canal Test Fishery	0	0	-	0	0	0	.000	.000	-
Non-H. Canal Terminal Net	606,700	559,600	8%	3,051	3,827	-776	.029	.052	-44%
Total	1,097,400	1,001,300	10%	26,207	18,478	7,729	.248	.250	-1%
GRAND TOTAL	5,536,900	5,213,200	6%	61,805	39,500	22,305	.585	.534	9%

[1] Natural impact and exploitation rate totals include all Canadian fisheries.
[2] Exploitation rate computed as landed catch divided by initial cohort.

Table 1.20. **Preseason predictions and postseason estimates of landed catch and exploitation rates for the Hood Canal natural coho stock in 1990. Negative deviations indicate negative impact upon predicted escapement of stock.**

FISHERY	TOTAL CATCH			HC NATURAL IMPACT			HC NATURAL EXPLOITATION RATE[2]		
	EXPECTED	ESTIMATED	DEVIATION	EXPECTED	ESTIMATED	DEVIATION	EXPECTED	ESTIMATED	DEVIATION
CANADA									
WCVI Troll	1,800,000	1,844,900	-2%	28,680	17,570	11,110	.233	.227	2%
GS Sport & Troll	912,100	773,600	18%	1,378	89	1,289	.011	.001	871%
Area 20 Net	175,000	142,900	22%	4,397	1,778	2,619	.036	.023	55%
Total[1]	2,887,100	2,761,400	5%	34,793	19,815	14,978	.282	.256	10%
U.S. OCEAN FISHERIES									
N. of Cape Falcon Troll	195,000	201,100	-3%	4,092	1,979	2,113	.033	.026	30%
N. of Cape Falcon Sport	405,000	279,200	45%	2,590	738	1,852	.021	.010	120%
S. of Falcon	475,900	435,300	9%	1,129	0	1,129	.009	.000	-
Total	1,075,900	915,600	18%	7,811	2,717	5,094	.063	.035	80%
PUGET SOUND FISHERIES									
Juan de Fuca Treaty Troll	2,900	1,900	53%	104	24	80	.001	.000	173%
Preterminal Sport	227,600	320,100	-29%	4,870	6,260	-1,390	.039	.081	-51%
Juan de Fuca Net	52,600	31,000	70%	1,153	687	466	.009	.009	5%
San Juan Net	115,700	104,900	10%	947	761	186	.008	.010	-22%
Area 6B/9 Net	0	9,700	-100%	0	1,056	-1,056	.000	.014	-100%
Hood Canal Terminal Sport	4,300	800	438%	1,393	98	1,295	.011	.001	792%
Hood Canal Terminal Net	78,600	39,100	101%	22,176	6,913	15,263	.180	.089	101%
Hood Canal Test Fishery	0	0	-	0	0	0	.000	.000	-
Non-H. Canal Terminal Net	523,500	721,300	-27%	2,828	12,355	-9,527	.023	.160	-86%
Total	1,005,200	1,228,800	-18%	33,471	28,154	5,317	.271	.364	-25%
GRAND TOTAL	4,968,200	4,905,800	1%	76,075	50,686	-12,300	.617	.655	-6%

[1] Natural impact and exploitation rate totals include all Canadian fisheries. NA - not available.
[2] Exploitation rates computed as landed catch divided by initial cohort.

1.4.4.2.4 Terminal Area Net Fishery Catches

Inseason updates for Hood Canal are estimated using CPUE as an indicator of the terminal run size. There are two problems with the Hood Canal updates. First, CPUE does not correlate adequately with run size until relatively late during the season. As a result, opportunities to adjust fishing schedules is limited to the last two or three weeks of the management period at best when the peak of the run is already past. The second problem is that the updates, once available, although generally better than the preseason forecasts, are still not very good indicators of run size.

In 1988, directed fisheries in all areas of Hood Canal managed for natural production were closed based on the preseason expectation of a very depressed run. As a result, there was no formal update. Despite the closures, escapement was still only 11,600; far short of the 19,100 escapement goal or even the expected escapement of 14,700 that had been planned for during the preseason process.

The update in 1989 correctly indicated that the run would be lower than expected based on the preseason forecast. However, the update did not adequately reflect the magnitude of the decline or indicate the need to restrict fisheries during the latter part of the management period. The update was complicated by a large and very early return of hatchery fish to Area 12A. This run was essentially over before the fishery in Area 12 that is used to update the run even started so there was considerable uncertainty about how this aberration in timing would affect the update for other components of the Hood Canal run. The escapement in 1989 was 15,300 compared to the 19,100 escapement goal. The directed harvest of coho totaled about 13,900 coho but only about 7,700 of these were taken after the first week in October when a useable update is likely to be available. Approximately 3,000 of these were wild fish that could have accrued to escapement. If we had perfect knowledge of the status of the run and closed all directed fisheries after the first week of October much of the shortfall in escapement would have been made up although the stock still would have been underescaped according to the definition of overfishing. Given the uncertainties typical of the update process, it is unrealistic to expect this sort of inseason management precision.

The update in 1990 also indicated that the run would be lower than had been expected but again did not reflect adequately the magnitude of the decline. The expected escapement was 19,100 compared to the post season estimate of 6,800. The total catch of coho during the management period in areas managed for natural production was 8,800. Only about 4,500 were taken after the first week in October and only about 1,200 were wild fish. It is therefore clear that the escapement shortfall was not related to shortcomings of the update process.

1.4.4.2.5 Harvest Rate Index

For the Big Beef stock, the estimated harvest rate index was 50 percent in 1988, 79 percent in 1989, and 90 percent in 1990.

Table 1.21. Comparison of preseason, final inseason estimate, and postseason estimate of the total Hood Canal terminal run size.

YEAR	PRESEASON FORECAST	FINAL INSEASON UPDATE	POSTSEASON ESTIMATE
1988	70,434	No Update	33,442
1989	120,900	96,502	68,930
1990	112,745	90,893	56,440

1.5 DISCUSSION

1.5.1 CHINOOK SALMON

1.5.1.1 Stock Assessment

The first objective of the review was to determine if sufficient fish were present to achieve the escapement objectives after accounting for mortality in Alaskan and Canadian fisheries. For the Skagit and Snohomish stocks, potential escapements were generally greater than the escapement goal. The potential escapement of the Snohomish fall stock exceeded the escapement goal (5,250) in each of the three years during the overfishing review period. During this period, the potential escapement ranged from 6,500 to 8,500 fish. For Skagit spring chinook, the potential escapement exceeded the escapement goal (3,000) in two of the three years. The Skagit potential escapement ranged from 4,700 fish in 1988 and 1989 to 2,900 fish in 1990, however, there is a problem accounting for Skagit spring chinook because the distinction between spring and summer/fall chinook is not clear.

In contrast, the potential escapement of the Stillaguamish stock was approximately 50 percent of the escapement goal (2,000) in the years 1988 through 1990. The potential escapement ranged from 906 fish in 1988 to 1,042 fish in 1990.

1.5.1.2 Management Planning

An important conclusion of this review is that fisheries under the jurisdiction of the PFMC have a minor impact at most upon the three chinook stocks assessed. The majority of fishing related mortality occurs in the Alaskan and Canadian fisheries. The Puget Sound fisheries also account for a significant proportion of the catch, ranging from about 35 to 50 percent, depending on the stock. The PFMC fisheries account for less than 1 percent of the catch related mortality for any of the stocks.

Since the potential escapement of the Skagit and Snohomish stocks generally exceeded the escapement objective, it was necessary to determine why the current management system allowed a harvest that exceeded the harvestable surplus.

One possible reason is that, unlike coho, there is no comprehensive preseason management system for chinook that attempts to manage all fisheries to achieve specific target escapements for specific chinook stocks. Management plans for mixed stock fisheries in the southern U.S. are based upon a variety of criteria, but a consistent management objective and linkage between the fisheries is lacking. Only in terminal net fisheries is stock-specific management action taken in response to inseason estimates of stock abundance. The patchwork of management planning has made it difficult to obtain an understanding of the total effect of all fisheries upon a stock. For example, planning of Puget Sound sport and troll fisheries is typically done at different times of the year, with different analytical tools, and with different management objectives. Thus, when the terminal run size forecast is for a run lower than the escapement goal, there are no actions taken in preterminal fisheries to try to allow for more of the run to get to the terminal area, and typically, the only management action is to close the terminal fisheries. If the terminal run size, however, is already lower than the escapement goal, then this management action would be inadequate to achieve the escapement goal.

One reason for the lack of comprehensive management of chinook has been the lack of a comprehensive fisheries assessment model, like the Coho Assessment Model. However, a chinook model that incorporates Puget Sound stocks and fisheries is nearly completed, and comprehensive management of chinook fisheries may be possible in the near future.

1.5.1.3 Stock Productivity

The lack of comprehensive management planning for chinook is not, however, the only explanation for why the stocks examined have not been achieving their escapement goals. For all three stocks, but especially for Stillaguamish chinook, there is evidence of a continuing long-term decline in stock productivity. The indicators related to stock productivity suggest that recruitment of the broods returning during the 1988-1990 period has been lower than recruitment for broods prior to this period. This is apparent for both the Stillaguamish and Snohomish stocks and is indicated by the declining trend both in the survival rate and in the potential escapement.

For the Snohomish stock, a negative trend in potential escapement has existed since 1980, and the potential escapement in the 1988-90 period was about 50 percent of the potential escapement in 1980, despite reductions in exploitation rates. Similarly, the potential escapement for Stillaguamish summer/fall chinook has not increased substantially despite reductions in the exploitation rates to near or below MSH levels. Part of the cause for this may be that the average survival rate for brood years 1984 through 1987 was approximately 70 percent less than the estimated average for the 1981 through 1983 broods. Reasons for this poor survival are unknown. It may be related to freshwater habitat deterioration, marine factors, climatic changes, disease, or all of the above.

For the Skagit stock, the declining trend is not evident, but the lack of trend may be due to the limited nature of the data available for this stock. Several key chinook stocks other than the three considered here have also exhibited lower survival in recent years, but there are other major chinook stocks (e.g., Green River, coastal fall stocks) that have exhibited increased survival during this period (Chinook Technical Committee 1991b).

The analysis indicated that exploitation rates for the Stillaguamish and Snohomish stocks have been reduced since the implementation of the Pacific Salmon Treaty. Comparison of current exploitation rates relative to those estimated for MSH gave mixed results. The adult equivalent exploitation of the Stillaguamish summer/fall stock has averaged 50 percent in recent years, which is below the estimated MSH rate. In contrast, the estimated exploitation rate on the Snohomish stock has averaged 11 percent higher than the MSH rate in recent years, and has exceeded the MSH rate in 9 of the last 11 years.

An MSH exploitation rate has not been computed for the Skagit spring stock. However, based on other stocks in Alaska, British Columbia, and Washington, it is likely to be in the range of 50 percent to 65 percent (Chinook Technical Committee 1991b). This would be approximately 17 to 36 percent less than the average estimated for the Skagit spring chinook stock, although, as stated previously (see Section 1.4.3.2.3.), it is likely that the Skagit exploitation rate has been overestimated, possibly by a significant amount.

Currently these three stocks appear to be less productive than previously assumed. The addition of the productivity estimates for the 1984-1986 broods to the database has decreased the estimates of the MSH harvest rates for each stock. For example, MSH harvest rate levels estimated for the Stillaguamish and Snohomish stocks dropped significantly when the most recent information on low stock productivity was added to the database (Chinook Technical Committee 1991a; Chinook Technical Committee 1991 Annual Report, in prep.). This sensitivity to new information is due both to the shortness of the time series of available data as well as possible long-term degradation of habitat in these systems. Unfortunately, even with a relatively long time series it is difficult to detect losses in production potential due to habitat degradation using spawner and production data alone (Reisenbechler 1989).

The chinook stocks considered here, along with many other stocks coast-wide, have been affected by recent years of low productivity. This factor likely contributed to the underescapement observed during the 1988-1990 time period. However these chinook stocks have been chronically underescaped at least since 1980, and for much longer than that in the case of the Stillaguamish. The Stillaguamish stock has consistently produced too few fish to meet the escapement goal since 1980 while the Snohomish stock's productivity has consistently been declining since then. Similar productivity estimates for the Skagit spring stock are not available.

The chronic depressed status of these stocks is likely due to a combination of harvest rates which are too high and natural productivity levels which are too low. This situation can only be improved by a combination of production initiatives and management planning. The production initiatives would include a combination of habitat protection and restoration along with strategic supplementation of the natural stocks using in-system broodstock. For example, a natural stock supplementation program initiated in 1985 for Stillaguamish chinook has the potential to accelerate rebuilding of this stock. Initial indications from the 1991 return are that a substantial portion of the natural escapement originated from the supplementation program. This kind of a stock supplementation program must be combined with a comprehensive long-term harvest management strategy which takes current productivity potential and all harvest of these stocks into account. The new chinook model developed by WDF and the NWIFC, and currently under review by the PFMC, should help fill some information gaps and will help facilitate more comprehensive planning and management of production and harvest of these stocks.

1.5.2 COHO SALMON

1.5.2.1 Stock Assessment

Failure of the Skagit natural coho and Hood Canal natural coho stocks to achieve the annual escapement objective was generally not due to insufficient recruitment. For both the Skagit and Hood Canal stocks in all years, sufficient fish were present even after Canadian fisheries to achieve the escapement objectives.

Since recruitment was sufficient, the primary focus of the analyses for coho salmon was to attempt to ascertain the management or analytic methods which resulted in escapements which were less than the objective. Potential explanations include 1) insufficient preseason management planning, 2) catches which exceeded preseason expectations, 3) erroneous predictions of abundance, or 4) erroneous predictions of exploitation rates. Each of these potential explanations is discussed in greater detail below.

1.5.2.2 Management Planning

Insufficient preseason planning is not the factor which resulted in the failure of the Skagit and Hood Canal stocks to achieve their annual escapement objectives. Puget Sound coho stocks are the subject of a comprehensive preseason planning process which encompasses all fisheries which operate south of the Canadian border. There are eight key naturally producing coho stocks that are used during the annual PFMC process for planning coho fisheries north of Cape Falcon including 4 from the Washington Coast and 4 from Puget Sound. At the beginning of each year, the controlling stock or stocks which limit the allowable harvest are identified based on preseason forecasts of abundance. In three out of the last six years, the Skagit stock was limiting (1987, 1989, and 1990). The Hood Canal stock was the controlling stock in 1988, 1991, and 1992. While this planning process is time consuming and often contentious, it does provide a means to develop a management plan for each year which takes into account current stock abundance. Although some viable alternatives exist to streamline the procedures (see 1.5.2.4. below), it is not likely that any alternative will increase the accuracy of the preseason projections.

1.5.2.3 Sources of Error

The preseason estimate of the target escapement rate (expected escapement divided by predicted recruits), the postseason estimate of the target escapement rate (expected escapement divided by estimated recruitment), and the estimated escapement rate (estimated escapement divided by estimated recruitment) are provided in Table 1.22. Since the expected escapement was identical for the pre- and postseason calculations of the target escapement rate, a difference in the target values indicates that the preseason estimate of recruitment differed from the postseason estimate. For the Hood Canal stock, the postseason estimate of recruitment was less than the preseason estimate in each of the 3 years examined, resulting in an increase in the target escapement rate. The postseason estimate of the target escapement rate for the Skagit stock was smaller than the preseason estimate for each of the years. For both stocks, the estimated escapement rate was less than the postseason target in all cases.

Table 1.22. Comparison of preseason and postseason estimates of the target escapement rate and the estimated escapement rate.

	SKAGIT			HOOD CANAL		
	1988	1989	1990	1988	1989	1990
Target Escapement Rate						
Preseason Estimate	21.2%	18.4%	17.7%	29.9%	18.1%	15.5%
Postseason Estimate	18.8%	11.6%	16.3%	30.1%	25.8%	24.7%
Estimated Escapement Rate	14.9%	10.2%	10.4%	22.6%	20.7%	8.8%

The primary fisheries responsible for deviations from the preseason prediction for the escapement of the

Hood Canal and Skagit natural stocks of coho salmon during the overfishing review period are summarized in Table 1.23. Fisheries were selected for which the difference between the preseason prediction and postseason estimate of the exploitation rate multiplied by the estimated recruitment differed by more than 5 percent of the escapement objective. Within the selected fisheries, the causative factor for the deviation was partitioned into 1) a deviation from the expected total catch (all stocks) in the fishery, 2) an error in the model prediction of the impact of the fishery upon the stock, or 3) both factors 1 and 2.

The partitioning process provides a means to more specifically identify the cause of the deviation from the preseason prediction. Note that errors resulting from factor 1 are associated with either mismanagement of fisheries with quotas, higher than expected catches in non-ceiling fisheries, or poor predictions of the catch in fisheries with only incidental catch. Errors resulting from factor 2 are associated with either poor predictions of recruitment or the performance of the prediction model (CAM).

Most of the primary factors (19 of the 30 factors, or 63 percent) identified in Table 1.23 were of the second type, associated with either poor recruitment predictions or with CAM performance. The problems with both the Hood Canal and the Skagit coho predictions were examined by the Science and Statistics Committee (SSC) of the PFMC in 1991. The committee noted:

> "The SSC still believes the accuracy of the abundance forecasts is limited by problems with the escapement estimates and run reconstructions" (SSC 1991).

Since the SSC review, staffs from the Puget Sound Tribes and WDF have worked on improving escapement estimates for Skagit coho and on improving run reconstruction techniques for all Puget Sound coho stocks. None of these improvements have been completed, but some of the work has been included in the databases used for developing predictions. In 1992, both the Skagit coho and the Hood Canal coho run predictions included information from the cohort reconstruction work (WDF et al. 1992). The prevalence of factor 2 in Table 1.23 also indicates that the performance of CAM needs to be examined, with resulting updates to the model.

Table 1.23. Primary factors which resulted in a deviation from the preseason prediction for the escapement of the Hood Canal and Skagit natural stocks of coho salmon in 1988, 1989, and 1990.

SOURCE OF ERROR	SKAGIT			HOOD CANAL		
	1988	1989	1990	1988	1989	1990
PREDICTED RECRUITMENT					X	X
WCVI TROLL						
Predicted Catch		X				
Modeling/Forecast Error	X	X	X			
GEORGIA STRAIT SPORT AND TROLL						
Predicted Catch	X					
AREA 20 NET						
Predicted Catch		X				
Modeling/Forecast Error		X				
SOUTH OF CAPE FALCON TROLL AND SPORT						
Modeling/Forecast Error	X			X		
NORTH OF CAPE FALCON TROLL						
Modeling/Forecast Error			X			
PUGET SOUND PRETERMINAL SPORT						
Predicted Catch			X			X
Modeling/Forecast Error			X	X		X
AREA 6B/9 NET						
Predicted Catch						X
Modeling/Forecast Error					X	
OTHER TERMINAL NET						
Predicted Catch	X		X	X		X
Modeling/Forecast Error			X	X	X	X
HOOD CANAL TERMINAL NET						
Modeling/Forecast Error				X		
SKAGIT TERMINAL NET						
Predicted Catch	X					
Modeling/Forecast Error	X					

1.5.2.3.1 Predicted Catch and Exploitation Rates

It is evident from Table 1.23 that catches in U.S. ocean waters in excess of preseason expectations was generally not the explanation for failure to achieve the escapement objectives. The total catch in PFMC fisheries was generally equal to or less than the preseason prediction. The existing system of quotas and inseason catch monitoring in PFMC fisheries appears to be working well, and major modifications are not required.

The most consistent source of deviation from the preseason prediction for escapement was the predicted catch and exploitation rates in Puget Sound terminal net fisheries directed at other stocks. Net fisheries included in this group include South Sound (primarily areas 10 and 11), Stillaguamish/Snohomish (primarily Area 8A), and Nooksack/Samish region (primarily areas 7B and 7C). Fisheries in these areas have typically been managed to harvest surplus production of local stocks. For example, the Area 10 fishery is managed with the intent of harvesting surplus production of South Sound stocks. However, these fisheries also harvest non-local stocks, such as the Skagit and Hood Canal natural stocks of coho.

Preseason estimates of the catch and exploitation rates for these fisheries were generally less than the postseason estimates in the years 1988 through 1990. This could result from a number of factors, which include 1) inseason estimates of abundance which exceeded preseason predictions and led to increased exploitation rates, 2) changes in fishing patterns which increased the exploitation rate on non-local stocks, or 3) errors in modeling procedures or parameters. The preseason prediction for the South Sound coho run was low in 1988, but the 1989 and 1990 forecasts were higher than the actual. All three of these factors are currently under review by the technical staffs of WDF, the NWIFC, and Puget Sound treaty tribes.

Failure of the Skagit stock to achieve the escapement objective may also be partially attributed to inaccurate predictions of exploitation rates in the WCVI troll fishery. The exploitation rate of Skagit fish in the WCVI troll fishery was higher than the preseason prediction each year from 1988 through 1990. This underestimate of exploitation may be only a random event that happened to occur in several consecutive years, but it may also be that the harvest rate inputs to the Coho Assessment Model (CAM) are biased low. A review of the base period harvest rates used to model the Skagit stock in CAM will need to occur before the cause of this is determined. For Hood Canal coho, the estimates of the WCVI troll exploitation rates were relatively accurate or overestimated.

It should be noted that correcting the preseason estimate of WCVI exploitation rate, if needed, is a different problem from trying to reduce the exploitation rate. As noted in Section 4, most of the catch of Hood Canal and Skagit coho occurs in Canadian fisheries, primarily the WCVI troll, Area 20 net, and Georgia Strait sport and troll fisheries. Reductions in the catch in these fisheries could greatly help the stock to achieve its escapement goal.

These fisheries, however, are managed by Canadian agencies, and the only influence U.S. agencies have on their management is through the Pacific Salmon Treaty negotiations. At the present time, only the WCVI troll fishery has a catch ceiling on coho, and this ceiling does not vary with coho abundance. The WCVI and Georgia Strait fisheries have chinook ceilings, but these also do not vary with abundance, and in recent years chinook abundance has been so low that the ceilings cannot even be approached. Major renegotiations will, however, occur before the 1993 season. There are possibilities that ceilings more responsive to abundance may be negotiated for some of the Canadian fisheries, and this could help to achieve escapement goals, but this is far from a certain outcome.

Although the coho stocks reviewed here are managed for fixed numerical point escapement goals, it is useful to compare the observed overall exploitation rates with theoretical rates associated with MSH. The MSH exploitation rate can be defined as the proportion of the run which is available for harvest as surplus production at a level of the stock which will maximize the amount of surplus production (Coho Technical Committee 1987). There are few studies which have directly determined the MSH exploitation rate for coho stocks, and none directly estimate this parameter for Puget Sound stocks. However, available information provides a reasonable range with which the realized exploitation rates in this study can be compared.

MSH exploitation rates have been estimated for a variety of coho stocks on the Pacific coast. Beidler et al. (1980) estimated a rate of slightly less than 70 percent for the composite of Oregon coastal natural stocks. For a composite of British Columbia coho stocks, Wong (1982) estimated a range of 70 to 72 percent for the MSH exploitation rate. Kadowaki (1988) estimated that the MSH rate for Skeena River coho in northern British Columbia is 62 percent. However, a more recent analysis, which includes more years of data and updated estimates of ocean catches using CWT data, resulted in a revised estimate of 71 percent for this stock (Kadowaki, pers. comm.). Holtby (1987) estimated a range of productivities for Carnation Creek stock on the west coast of Vancouver Island. The MSH exploitation rate ranged from 61 percent, during periods of the lowest freshwater productivity, to 75 percent during periods of the highest freshwater productivity. He also noted that lower than average marine survivals could temporarily lower the MSH exploitation rate.

In considering the available information, the Pacific Salmon Commission's Coho Technical Committee felt that Puget Sound coho stocks had the capability of being more productive than the stocks referenced above. They also recognized that the MSH exploitation rate varies considerably among stocks and among years. They estimated a range of MSH rates from 60 to 85 percent for Puget Sound coho stocks, based on assumed ranges of smolts per female and marine survival (Coho Technical Committee 1987). Based on the available information, the Pacific Stock Assessment Review Committee in Canada recommended a target range of 65 to 70 percent for the exploitation rate of coho stocks originating in southern British Columbia (Stocker et al. 1989). Hayman (1983) completed a spawner/recruit analysis for Skagit River wild coho, one of the stocks reviewed in this report. However, his results are not directly usable in terms of overall exploitation rate because the analysis was based on returns to Washington waters rather than recruitment to all fisheries.

Observed fishery exploitation rates for Skagit coho were within a range of 65-73 percent for the period reviewed in this report (section 1.4.3.3.5). This range appears to be within levels appropriate for Puget Sound coho stocks, as reviewed above. This range may be greater than the appropriate MSH levels during periods of low freshwater or marine survival.

The observed fishery exploitation rate for Hood Canal coho of 50 percent in 1988 (section 1.4.4.2.5) was below the appropriate MSH range. In contrast, the observed rates of 79 percent in 1989 and 90 percent in 1990 were likely greatly in excess of the appropriate level for maximum sustainable harvest, especially if marine survivals were lower than average for those broods.

1.5.2.3.2 Preseason Estimates of Abundance

Inaccurate preseason estimates and resulting high exploitation rates were the primary factor which resulted in the failure of the Hood Canal stock to achieve its escapement objective in 1989 and 1990. The relative error of the preseason prediction was 43 percent in 1989 and 59 percent in 1990. Deviations from the escapement objective in these years could have been substantially more severe if net fisheries in Hood Canal had not been curtailed. Preseason estimates of abundance for the Skagit stock were less than the postseason estimate in each of the three years, with relative errors of -8 to -37 percent.

1.5.2.3.3 Quality of Escapement and Escapement Goal Estimates

Recently, a number of concerns have been raised about the currently used escapement goals as developed by Zillges (1977). Reassessments of the actual amount of stream area available for smolt production in the Skagit River and in coastal streams (Johnson 1986; SSC 1990) have resulted in increased estimates of available rearing area. More recent information on habitat to smolt production rates (Johnson 1986; Baranski 1989) suggest that lower rates may be appropriate for some streams. The average smolt to female production rate in several study streams (Bingham Creek, South Fork Skykomish, Big Beef Creek) appears to be lower than originally estimated (Seiler 1989a; Seiler 1991; Flint pers. comm.). Morishima (1981) raised a more fundamental question about using these escapement goals for producing the maximum sustainable harvest. The underlying assumption of these goals is that the optimum escapement level is that which maximizes smolt, and therefore adult, production. He noted that a basic tenant of spawner/recruit theory is that the escapement level that produces the maximum sustainable harvest is lower than that which produces the maximum adult return.

The Puget Sound coho escapement estimation methods were recently reviewed by the Scientific and Statistical Committee (SSC) of the PFMC; they made three general observations. The first was the proportion of the coho spawning area that is actually surveyed is quite small: for instance, less than three percent in the Snohomish system (Flint 1988). A second was that the sampling was designed to survey fixed sections of the streams (the index sections), implicitly assuming that 1) index sections are representative of the entire basin, and 2) the spatial distribution of spawners is the same at all spawning densities and flow regimes. The final observation is that:

> "The base year method is the weakest feature of Puget Sound spawning escapement estimates, both conceptually and in execution. The relationship between base year escapements and AUC estimates is unknown and untested. As currently used, a linear relationship passing through the origin is assumed. In practice, additional error is introduced because the base year escapements are, for many basins, gross estimates. For most basins documentation of the methods used to arrive at these estimates is lacking ...
>
> The SSC feels strongly that the base year method for expanding AUC estimates to total spawning escapement is seriously inadequate as implemented ..." (Pacific Fishery Management Council 1990)

1.5.2.4 Addressing Data Quality Problems

It is possible to improve the accuracy of the preseason predictions and the postseason escapement estimates. One promising method would be to forecast Puget Sound runs in terms of total recruitment, rather than in terms of the terminal run size. Prior to this review, agreed-to estimates of total recruitment did not exist for Puget Sound runs; consequently, forecasts were done in terms of the terminal run size expected after an assumed level of interceptions takes place. This required iterative model runs to derive recruitment forecasts which made it difficult to evaluate the factors that might affect recruitment. Now that a method has been developed to generate estimates of total recruitment, it should be possible to forecast total recruitment directly for Puget Sound stocks in the near future. An improved recruitment database will also facilitate the incorporation of indicators of marine survival into the forecast.

Regarding the escapement estimation problems noted above, intensive evaluations of coho escapement estimates have been conducted on the Skagit, Skokomish, and Chehalis River systems over the last several years. When the analyses of these studies are completed, it is expected that the accuracy of the current escapement estimates will be significantly improved.

1.5.2.5 Options for Improving Coho Management

Even after improvements are made in data quality, however, the salmon database is so short, and the factors that affect salmon abundance so variable, that it is unlikely that our predictions will ever be as precise as the current management system requires. Viable alternatives to this management system do exist, however, which could streamline the preseason planning process for coho and reduce its dependence upon highly accurate preseason forecasts. The results from this report suggest ways to improve the preseason planning process. General suggestions for improving the coho management system include:

1) Develop a management system with reduced reliance on preseason abundance forecasts. The magnitude of errors in preseason forecasts are such that it may be preferable to consider a number of key stocks (rather than a single stock) when setting coho fishing regimes.

2) Plan and manage fisheries at a level of detail consistent with the appropriate use of available data. Given the annual variability in the distribution of coho, and the magnitude of errors in forecasts of recruitment and estimates of stock composition, the level of resolution of time and area strata currently used may be inappropriate.

3) Develop a mechanism to account for management uncertainty. Except for inseason adjustments made in terminal areas, the current system, including agreements for non-PFMC fisheries, does not enable fisheries to respond to deviations from predicted levels of recruitment. Because of natural variability in the predictions, escapements below the target level would be expected to occur approximately half the time. If managers consider this undesirable then a "buffer" could be established to account for uncertainty and escapement predictions could be expressed as a range rather than a point estimate.

One option, which was presented by the U.S. Southern Panel at the Coho Workshop (a Pacific Salmon Commission forum), is the "Stepped Harvest Management Approach" (U.S. Southern Panel 1992). Under this approach, a set of discrete, predefined fishery levels would be established for each fishery, with each level corresponding to a broad range of stock abundances of key natural stocks. Thus, over a broad range of forecasts, fisheries levels would not be changed, and when abundance is outside of this range (either lower or higher), the fisheries would step by discrete, predefined amounts. The fisheries levels would be set so as to provide stock protection and achieve allocation and escapement goals on average over several years. Such a system should end the phenomenon of small changes in forecasts causing large changes in fisheries levels, and reduce the amount of time spent negotiating annually what those levels should be. Among the cited advantages of this approach are:

1. Reduced reliance on the accuracy of preseason forecasts. Forecasts would still be needed but they would need to be accurate only to general degree.

2. Reduced sensitivity to data uncertainty. Management detail would be more consistent with the available data. Since fishery levels would be predefined, there would also be less incentive toward micro-management measures that, given the variability in coho distribution and forecasts, are unlikely to change actual impacts.

3. More stable and consistent fisheries.

4. Resource protection actions would be predefined for all fisheries.

5. Reduced time and resources required for annual management planning.

The stepped harvest management approach would be less sensitive to data quality problems, but it would not by itself improve the data quality. Regardless which management system is used, the natural variability in the predictions and updates would cause escapements below the target levels to be expected approximately half the time. It would not be unusual for overfishing, as defined by the PFMC, to occur for a stock three times consecutively just by chance. If managers consider this undesirable, then a buffer could be established to account for uncertainty, or escapement predictions could be expressed as a range rather than a point estimate.

1.6 RECOMMENDATIONS

1.6.1 Chinook Salmon

The chronically depressed status of the chinook stocks considered in this report is likely due to a combination of exploitation rates which are too great and reduced productivity due to degradation of habitat. The excessive exploitation rates may stem in part from the lack of a consistent management objective and the absence of a comprehensive management forum for Puget Sound chinook. The PSSSRG recommends:

- ***Create an annual management forum for Puget Sound chinook which establishes a common management objective for troll, sport, and net fisheries in Puget Sound.***

- ***Utilize a consistent analytic tool for assessing the impacts of all fisheries upon Puget Sound stocks of chinook.***

- ***Evaluate enhancement options which are consistent with natural stock management and can be used to speed rebuilding of depressed chinook stocks.***

1.6.2 Coho Salmon

The primary factors which resulted in the failure of the Hood Canal and Skagit natural coho stocks to achieve escapement objectives were 1) underestimates of the exploitation of these stocks in Puget Sound terminal net fisheries outside of the terminal areas for the Skagit and Hood Canal stocks, 2) preseason forecasts for the Hood Canal stock in 1989 and 1990 which were too great, and 3) underestimates of the exploitation of the Skagit stock in the west coast Vancouver Island (WCVI) troll fishery. Other factors which contributed to the failure to achieve escapement objectives are discussed in the text. The PSSSRG recommends:

- ***Establish a management framework, such as the "Stepped Harvest Management Approach", which streamlines the preseason planning process and reduces its dependence upon preseason estimates of abundance and exploitation.***

- ***Conduct annual postseason assessments of stock abundance and exploitation rates, and use these to improve the run prediction database.***

- ***Evaluate and update the Coho Assessment Model based upon the results from the annual postseason evaluation particularly with respect to the level of temporal and fishery stratification used in the model.***

1.6.3 General Data Needs

The PSSSRG identified the following data needs for both chinook and coho salmon.

- ***Identify and quantify those factors in the freshwater and marine habitat which limit the*** *productivity of chinook and coho salmon stocks. Initiate programs to protect, rehabilitate, and enhance critical habitat with particular emphasis on the limiting factors.*

- *Insure that stocks representative of the "overfished" stocks are tagged on an annual basis.*

- *Review escapement estimation methods, including the stray rates of tagged hatchery indicator stocks, and recommend improvements to the methods as necessary.*

- *Review the appropriateness of the current escapement goals.*

- *Continue development of improved preseason forecasts with an emphasis on obtaining direct estimates of total recruitment which include indicators of marine survival.*

1.7 ACKNOWLEDGEMENTS

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1.8 REFERENCES CITED

Ames, J. and D.E. Phinney. 1977. 1977 Puget/Sound summer/fall chinook methodology: Escapement estimates and goals, run size forecasts, and inseason run size updates. Washington Department of Fisheries Tech. Rept. No. 29.

Baranski, C. 1989. Coho smolt production in ten Puget Sound streams. Washington Department of Fisheries Tech. Rept. No. 99.

Beidler, W.M., T.E. Nickleson, and A.M. McGie. 1980. Escapements goals for coho salmon in coastal Oregon streams. Oregon Department of Fish and Wildlife Inf. Rept. Ser. No. 80-10.

Chapman, D.W. 1965. Net production of juvenile coho salmon in three Oregon streams. Trans. Amer. Fish. Soc. 94: 40-52.

Chinook Technical Committee. 1988. Pacific Salmon Commission Joint Technical Committee 1987 Annual Report. Pacific Salmon Commission, Report TCCHINOOK (88)-02.

Chinook Technical Committee. 1991a. User's guide to the Chinook Technical Committee chinook model. Unpublished report.

Chinook Technical Committee. 1991b. Joint Chinook Technical Committee 1990 annual report. Pacific Salmon Commission, Report TCCHINOOK (91)-03.

Coho Technical Committee. 1987. Response to Southern Panel questions. Pacific Salmon Commission, Report TCCOHO (87)-01.

Dygert, P. 1991. Hood Canal wild coho forecast methodology review. Unpublished report prepared for Scientific and Statistical Committee of the Pacific Fishery Management Council. 23 pp.

Flint, T. 1983. Methods for estimation of Puget Sound coho salmon escapements. Draft report, Washington Department of Fisheries, Olympia, WA, USA.

Flint, T. 1988. Example of Puget Sound escapement methodology - Snohomish River, 1988. Unpublished report, Washington Department of Fisheries, Olympia, WA, USA.

Hayman, R.A. 1983. Calculation of the escapement level at maximum surplus production for Skagit River wild coho. Skagit System Cooperative Technical Report No. 83-1.

Hayman, R. 1991. Review of Skagit coho forecast methods. Unpublished report prepared for Scientific and Statistical Committee of the Pacific Fishery Management Council.

Holtby, L.B. 1987. The effects of logging on the coho salmon of Carnation Creek, British Columbia. Pages 159-174 *in* T.W. Chamberlin, editor. Proceedings of the workshop applying 15 years of Carnation Creek results. Carnation Creek Steering Committee, Pacific Biological Station, Nanaimo, B.C., Canada.

Johnson, R. 1986. Assessment of the Skagit River system's coho rearing potential. Washington Department of Fisheries Tech. Rept. No. 95.

Kadowaki, R.K. 1988. Stock assessment of early run Skeena River coho salmon and recommendations for management. Can. Tech. Rep. Fish. Aquat. Sci. No. 1638.

Lister, D.B. and C.E. Walker. 1966. The effect of flow control on freshwater survival of chum, coho, and chinook salmon in the Big Qualicum River. Can. Fish. Cult. 37: 3-25.

Morishima, G. 1981. A primer on spawning escapement goals. Unpublished report. Quinault Management Center, Mercer Island, WA, USA.

Reisenbechler, R. 1989. Utility of spawner-recruit relations for evaluating the effects of degraded environment on the abundance of chinook salmon. Pages 21-32 *in* C.D. Levings, L.B. Holtby, and M.A. Henderson, editors. Proceedings of the National Workshop on Effects of habitat alteration on salmonid stocks. Can. Spec. Publ. Fish. Aquat. Sci. 105.

Salo, E. and W.H. Bayliff. 1958. Artificial and natural production of silver salmon (Oncorhynchus kitsutch), at Minter Creek, Washington. Washington Department of Fisheries, Res. Bull. No. 4.

Science and Statistics Committee. 1990. Review of Washington coastal and Puget Sound coho salmon escapement estimation methodologies: Summary and recommendations. Pacific Fisheries Management Council, Portland, OR, USA.

Science and Statistics Committee. 1991. Comments on methodology reviews. Pacific Fisheries Management Council, SSC Supplemental Report F.3.

Scott, J.B. Jr. 1988. Coho fishery management assessment model user's manual. Unpublished report, Northwest Indian Fisheries Commission, Olympia, WA, USA.

Seiler, D. 1989a. Forecast of 1989 wild coho run to Grays Harbor. Internal memo, Washington Department of Fisheries, Olympia, WA, USA.

Seiler, D. 1989b. Sex composition of wild coho escapements. Internal memo, Washington Department of Fisheries, Olympia, WA, USA.

Seiler, D. 1991. Coho production potential above Snoqualmie Falls. Internal memo, Washington Department of Fisheries, Olympia, WA, USA.

Stocker, M., N. Bourne, B. Riddell, J. Schweigert, and A. Tyler (eds.) 1989. Pacific Stock Assessment Review Committee (PSARC) Annual Report for 1988. Can. MS Rep. Fish. Aquat. Sci. 2020.

U.S. Southern Panel. 1992. Stepped harvest management approach for coho. Unpublished manuscript. Presented at the Pacific Salmon Commission Coho Workshop, February 1992, Victoria, BC, Canada.

Washington Department of Fisheries, Puget Sound Treaty Tribes, Northwest Indian Fisheries Commission. 1992. 1992 Puget Sound coho salmon forecast methodology. Documentation prepared for the Science and Statistics Committee, Pacific Fisheries Management Council, Portland, OR, USA.

Williams, W.R., R.M. Laramie, and J.J. Ames. 1975. A catalogue of Washington streams and salmon utilization. Vol. 1 - Puget Sound. Washington Department of Fisheries, Olympia, WA, USA.

Wong, F.Y.C. 1982. Analysis of stock-recruitment dynamics of British Columbia salmon. Master's thesis. University of British Columbia, Vancouver, B.C., Canada.

Zillges, G. 1977. Methodology for determining Puget Sound coho escapement goals, escapement estimates, 1977 preseason run size prediction and inseason run assessment. Washington Department of Fisheries Tech. Rept. No. 28.

Appendix Table 1.1. Tag groups used for analysis of distribution of mortality among fisheries of Stillaguamish natural summer/fall chinook.

Tag Code	Brood Year	Release Location	Number Tagged
050843	1980	Stillaguamish Tribs.	59,274
051063	1981	Stillaguamish Tribs.	46,186
051427	1982	Stillaguamish River, SF	33,444
211618	1983	Stillaguamish River, NF	26,915
212221	1986	Stillaguamish River, NF	23,904
212555	1987	Stillaguamish River, NF	127,910
213147	1988	Fortson Creek	36,599

Appendix Table 1.2. **Tag groups used for analysis of distribution of mortality among fisheries and cohort analysis of Skagit natural spring chinook.**

Tag Code	Brood Year	Tag Location	Number Tagged
632606	1981	Skagit Hatchery	9,481
632607	1982	Skagit Hatchery	58,453
632608	1983	Skagit Hatchery	35,893
633353	1984	Skagit Hatchery	13,324
633354	1984	Skagit Hatchery	13,377
633323	1985	Skagit Hatchery	47,521
633313	1986	Skagit Hatchery	90,882
633314	1986	Skagit Hatchery	80,395
634744	1987	Skagit Hatchery	63,808
634902	1987	Skagit Hatchery	25,725
635026	1987	Skagit Hatchery	25,379

Appendix Table 1.3. **Tag groups used for cohort reconstruction of brood year 1985 Skagit River natural coho.**

Tag Code	Brood Year	Tag Location	Number Tagged
212132	1985	Ross Isl. Slough	14,566
212135	1985	Suiattle R. Tribs.	13,796
212137	1985	Etach Crk.	8,683
212138	1985	Nookachamps Crk.	5,016
212141	1985	Mannser Crk.	8,692
212142	1985	Hamilton Slough	5,020
212238	1985	Sauk R. Tribs.	6,229
633651	1985	Baker R.	25,021
633652	1985	Baker R.	24,784
633653	1985	Baker R.	25,059
633654	1985	Baker R.	25,717
634225	1985	Skagit Hatchery	44,518
		Brood 1985 Total	207,101

Appendix Table 1.4. **Tag groups used for cohort reconstruction of brood year 1986 Skagit River natural coho.**

Tag Code	Brood Year	Tag Location	Number Tagged
212659	1986	Sauk R. Slough	1,704
212661	1986	Etach Crk.	4,512
212662	1986	Etach Crk.	10,412
212801	1986	Careys Crk.	5,891
212802	1986	Sauk R. Slough	8,318
212804	1986	Nookachamps Crk.	2,109
212808	1986	Ross Isl. Slough	6,319
212811	1986	Mannser Crk.	7,987
212813	1986	Carpenter Crk.	9,532
633711	1986	Skagit Hatchery	15,017
633712	1986	Skagit Hatchery	14,991
633713	1986	Skagit Hatchery	15,001
633916	1986	Baker Lake	9,192
634711	1986	Baker R.	24,730
634713	1986	Baker R.	24,971
634928	1986	Baker Lake	24,810
		Brood 1986 Total	185,496

Appendix Table 1.5. **Tag groups used for cohort reconstruction of brood year 1987 Skagit River natural coho.**

Tag Code	Brood Year	Tag Location	Number Tagged
213162	1987	Carpenter Crk.	7,344
213201	1987	Etach Crk.	8,941
213202	1987	Skagit R. Tribs.	45,289
213242	1987	Sauk R. Slough	5,466
213244	1987	Skagit R. Tribs.	3,268
630149	1987	Skagit Hatchery	45,662
630216	1987	Skagit Hatchery	3,256
630219	1987	Skagit Hatchery	3,270
630221	1987	Skagit Hatchery	3,258
630222	1987	Skagit Hatchery	3,262
635055	1987	Baker Lake	25,197
635056	1987	Baker Lake	24,644
635522	1987	Baker Lake	24,264
635525	1987	Baker Lake	24,404
		Brood 1987 Total	227,525

Appendix Table 1.6. **Tag groups used for cohort reconstruction of Hood Canal natural coho.**

Tag Code	Brood Year	Tag Location	Number Tagged
212225	1985	Skokomish R.	7,308
634241	1985	Big Beef Crk.	9,665
212814	1986	Skokomish R.	5,811
635041	1986	Big Beef Crk.	16,858
211729	1987	Skokomish R.	8,071
630432	1987	Big Beef Crk.	14,323

CHAPTER 2. STATUS AND TRENDS OF FISH HABITAT

2.1 INTRODUCTION

Chapter 2 of this report describes the factors affecting the general status of salmonid habitat within Washington State and in particular the Snohomish, Stillaguamish, Skagit rivers, the Hood Canal basin, and the Puget Sound Basin. This description relies on measures of human activities which are influencing fisheries habitat quantity and quality. This information cannot be taken as a direct measure of habitat condition since a number of physical, biological, and regulatory factors will influence the exact nature and magnitude of impacts to habitat caused by human activity.

Systematic and periodic assessments of fish habitat conditions have not been routinely conducted within Washington state. The lack of such assessments makes it impossible to directly document general trends of habitat condition throughout the state and within individual regions or watersheds. However, the relationships between land use and habitat changes have been well documented by research and local habitat monitoring programs. The fact that the relationships between freshwater habitat conditions and salmon production cannot yet be precisely quantified does not mean that these relationships are not strong and important. This report provides a summary of currently available information on salmonid habitat conditions and trends which affect the stocks of concern. More work is required to fully elucidate the key relationships.

2.2 PUGET SOUND BASIN

2.2.1 HUMAN POPULATION

Human population growth is probably the best overall measure of landscape wide disturbance to salmonid habitat. Population growth is accompanied by a number of land use changes which affect habitat. These land uses include urbanization, municipal and industrial water use, hydroelectric development, flood control, shoreline development, forest conversion, waste disposal, industrialization, and agriculture. Effects of these land uses on habitat include loss riparian vegetation, changes in hydrologic regime, wetland loss and degradation, increased erosion, water quality degradation, loss of habitat complexity and diversity, and creation of migration barriers. While low local or regional human population does not necessarily imply low habitat disturbance, high population is inevitably accompanied by high intensity land use and habitat disturbance. The population within Washington state has shown continuous growth since the national census in 1880 (Fig. 2.1).

In April 1990, total population of Washington was 4,798,100 (OFM 1990). Growth is expected to continue and is projected to be over six million by the year 2010 and 7 million by 2020 (OFM 1992).

Average statewide population density has increased from 1.1 persons/square mile in 1880 to 73.1 persons/square mile in 1990. Average density in the year 2010 is estimated to be 90 persons/square mile. Average population densities are somewhat misleading. The population within Washington is heavily concentrated in several areas and growth has not been evenly distributed across the state. In the 1970s, 75% of the states population lived in western Washington. Since 1980 this proportion has grown to 78% (OFM 1991b). Population growth for King, Kitsap, Pierce, Snohomish, and Thurston counties accounts

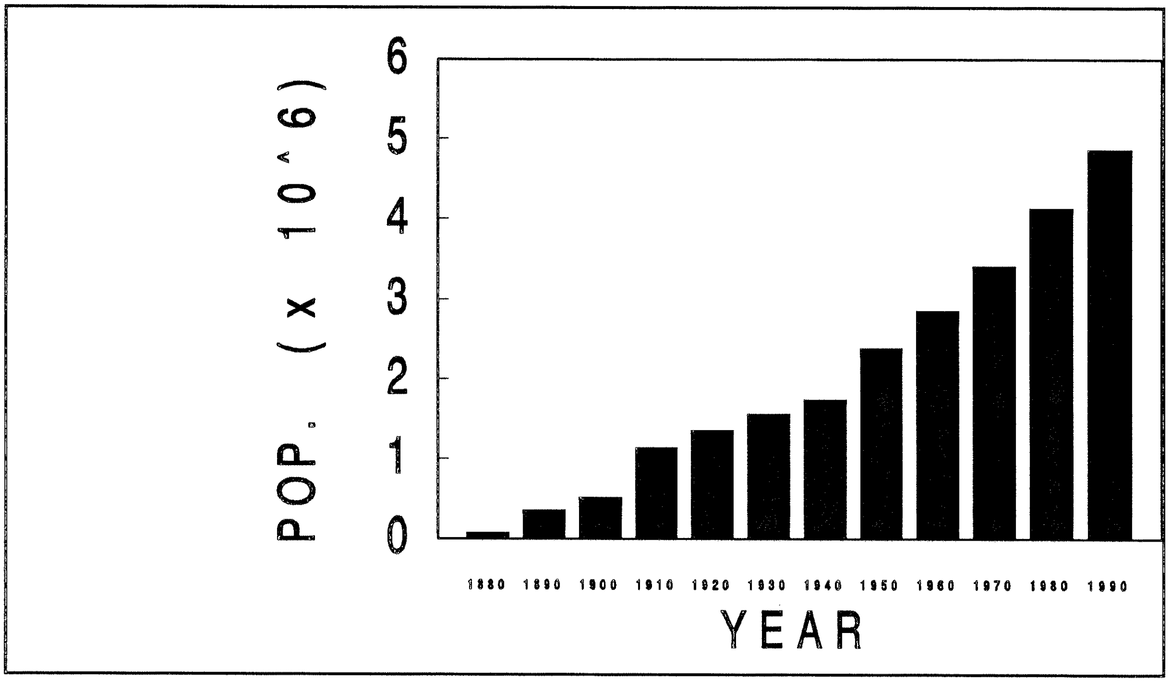

Figure 2.1. Growth of Washington State human population 1880-1990. (OFM 1990).

for 74% of the states population growth since 1980. Population densities for selected western Washington counties encompassing the Snohomish, Stillaguamish, and Skagit rivers and Hood Canal are shown in Table 2.1. Future growth is expected to continue to be concentrated largely within Western Washington (OFM 1991b).

Table 2.1. Population density and ranks of counties encompassing river systems of interest in this report.

County (System Affected)	1990 population density (persons/sq. mile)	Statewide Rank (of 39)
Jefferson (Hood Canal)	11.9	29
King (Snohomish)	725.4	1
Kitsap (Hood Canal)	496.2	2
Mason (Hood Canal)	41.5	15
Skagit (Skagit)	47.7	13
Snohomish (Stillaguamish/Snohomish)	231.6	6

Another trend of interest is the proportion of the state population located in incorporated and unincorporated areas since 1880. There was a period of general urbanization in the early 1900s but a steady trend towards growth in unincorporated areas since 1930. This trend implies increasing disturbance to habitats now located in rural areas and a shift from agricultural and forestry related impacts toward those associated with urbanization. Future land use trends associated with expected population growth have been estimated for the Puget Sound Basin and are shown in Table 2.2.

This information shows a long term trend of increasing population within the state, a concentration of population and growth within Western Washington, and a general move towards increasing growth in unincorporated areas of the state. With the exception of Jefferson county, the counties encompassing the Snohomish, Stillaguamish, Skagit, and Hood Canal systems rank among the highest growth and population density areas within the state.

Table 2.2. Estimated area of land use in the Puget Sound water quality planning area (Thousands of acres). (PSWQA 1986)

Land Use	1967	1984	2000
Intense Urban	308.4	509.4	824.0
Pasture land	467.6	248.8	248.8
Cropland	230.4	245.8	245.8
Streets and Highways	120.0	273.5	273.5
Rural, non-farm	238.8	270.0	466.9
Forest	7,191.6	7,009.3	6,497. 8
Total	8,556.8	8,556.8	8,556.8

2.2.2 SHORELINE PERMIT HISTORY

Accompanying growth within the state is increasing development of shoreline and upland areas for the purposes of housing, commerce, transportation, and other human uses. The issuance of state shoreline permits regulated under the Washington Shoreline Management Act of 1971 closely follows population growth within the state (Fig. 2.2). Permits are required for development activities within 200 feet of shorelines of the state. The permits are issued by local governments and counties whose programs are developed under state guidelines. The shoreline program is intended to reduce or eliminate impacts to the shoreline and associated waterbody, however the efficacy of this program is not known. It is likely that some effects to instream habitat are occurring from projects permitted under this program, however the numbers described here are intended to serve as an indicator of development activities in close proximity to aquatic habitats.

Permit numbers by county were not available for the preparation of this report, however, it is likely that permit applications are strongly associated with the relative population growth within the counties.

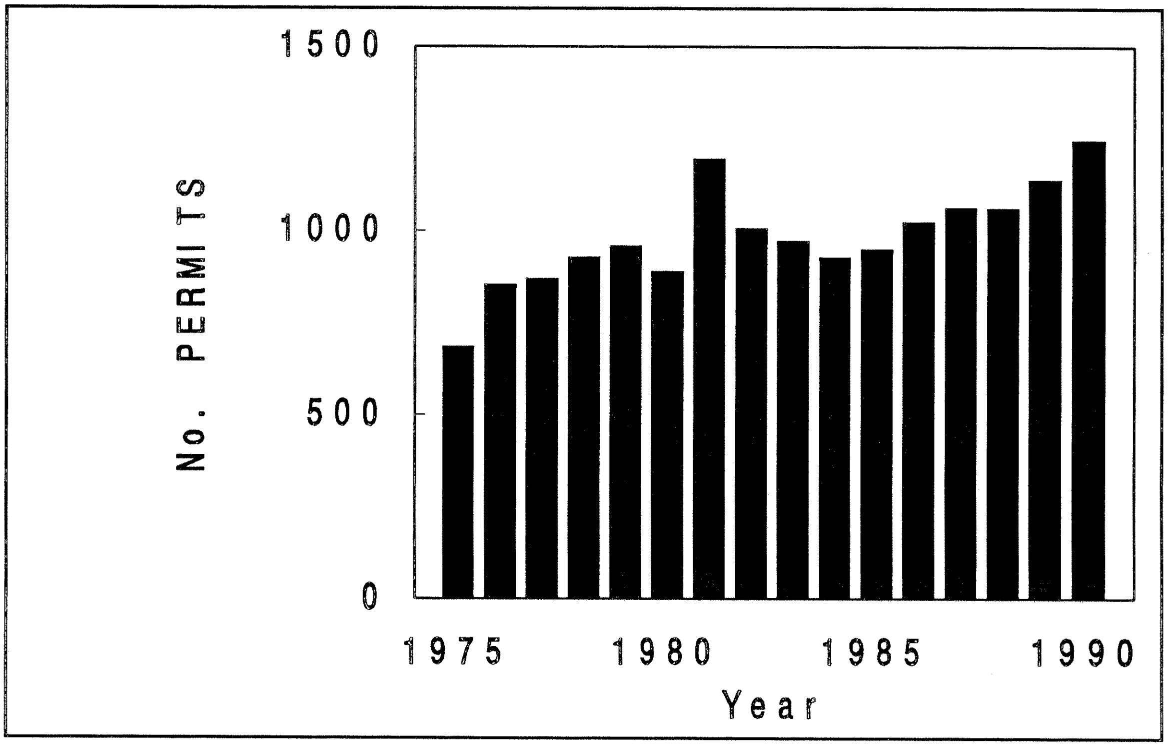

Figure 2.2. Trend in numbers of shoreline permits issued in Washington State 1975-1990.

Developments occurring in shoreline areas may result in loss of riparian vegetation, alterations in surface water runoff patterns, increased disturbance of fish by humans and domestic animals, and increased demand for flood and erosion control.

2.2.3 WATER RIGHTS APPLICATIONS AND PERMITS

The number of applications for water rights have also shown an increasing trend in recent years. Water rights applications are required for withdrawal of surface and ground waters of the state, with the exception of single family and small livestock watering use. There has been a general increase in the number of applications accepted by the Department of Ecology since 1984, however, the actual number of permits issued has been declining (WDOE 1991). This decline is in part due to the increasing workload on DOE staff, increased conflicts between instream and out of stream interests, an increasing number of closed or over appropriated streams, and regulatory appeals. DOE projects an increase in accepted permits and permit issuance during the next several years due to anticipated resolution of regulatory conflicts.

A majority of the increase in application numbers has been concentrated in the high growth areas of the state. The Northwest regional office (NWRO) and Southwest regional office (SWRO), which encompass the systems discussed in this report, have experienced significant increases in active pending water right applications.

Data for past water appropriations were not available for this report, but the general trend of increased permits for the purposes of development and private use indicates a strong relationship between population growth and out of stream water uses. Development includes such uses as residential subdivisions, short plats, golf courses, and commercial and recreational facilities. Private use includes small private water supplies including single and group domestic, small livestock needs, fish ponds, and small amounts of irrigation. Agriculture uses also represent a major source of new and pending water right applications.

Increased out of stream water use inevitably reduces instream flows. Water projects which include large storage reservoirs can take advantage of storing water during high runoff periods and still provide minimum instream flows during low flow periods. Small diversions, such as those which are exempt from state water permitting requirements, compete directly with fish habitat needs during low flow periods. In addition, a number of streams are overappropriated for permitted water withdrawals, and many streams, including the Stillaguamish, Skagit, and Hood Canal tributaries do not have state established minimum instream flows.

2.2.4 WETLANDS

The loss of wetlands has been extensive throughout the Puget Sound area. (PSWQA 1986). Wetland areas have been diked and drained for agricultural and residential uses, filled for industrial and urban use, and disconnected from their river systems by diking and dredging associated with flood control projects. Wetlands are now known to be critical summer and winter habitat for resident salmonids, especially juvenile coho and chinook salmon. Wetlands in estuary areas are also known to be important feeding and holding areas for smolting salmonids during their transition from fresh water to marine water. Table 2.3 shows the estimate river delta wetland losses of several rivers of interest. These figures represent the loss of only those wetlands found at the extreme lower portions of the river systems.

Table 2.3. Comparison of historical and present wetland areas at selected river deltas (acres).

River	Historical	Present	% Change
Snohomish	9,635	2,470	-74%[A]
Stillaguamish			-80%[B]
Skagit			-90%[C]
Skokomish	520	345	-34%[A]

[A] (PSWQA 1988)

[B] Tulalip Tribes estimate (D. Somers, Tulalip Fisheries Dept.)

[C] (PSWQA 1990)

2.2.5 FOREST PRACTICES

Lands managed for timber production represent a large percentage of the lands within western Washington counties. Table 2.4 shows the area of timberland and non-timberland in 1990 within selected counties encompassing the systems of interest (USDA 1991). Acreage of land managed for forest products decreased somewhat between 1979 and 1989. Decreases are due principally to conversion to residential and non-forest commercial uses.

Table 2.4. **Area of timberland within selected Puget Sound counties.**

County	Timberland (1,000 acres)	Non-timberland
King	863	490
Kitsap	156	97
Skagit	752	361
Snohomish	914	435

Ownership of the lands described in Table 2.4 is mixed between the federal government, the state, and large and small acreage private landowners. Figure 2.3 shows relative percentages of ownership within the selected counties.

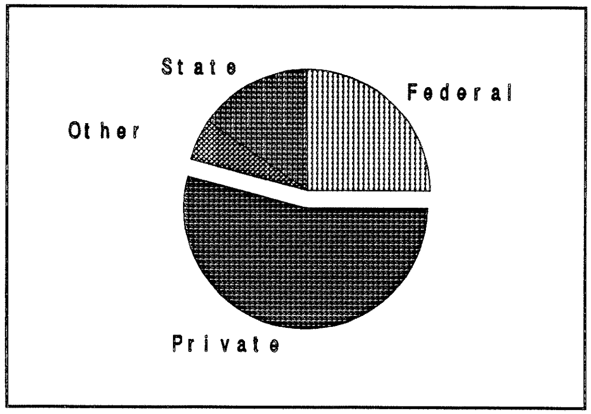

Figure 2.3. Distribution of public and private ownership of timberlands for the four counties listed in Table 2.5.

Recent trends in the number of forest practice applications for activities on non-federal lands show a dramatic increase since 1989 (WDNR 1991). This increase may be due to several factors including increased demand for wood, increased prices, fear of future regulatory restrictions, increased activity by small-acreage land owners, and conversion of timberlands to non-forest uses.

Total volume of timber harvested from private, state, and federal land in Western Washington has generally increased since 1949 (Fig. 2.4.). Timber harvest results in a number of negative impacts to fish habitat. Logging inevitably increased erosion which results in increased sedimentation of habitat. Erosion from logging, in some situations, has been shown to increased sedimentation rates as much as thirty times (Chamberlin et al. 1991). These increases are due to erosion which are the result of road construction and use; deep and shallow seated landslides caused by loss of root strength, debris torrents, and road failures; and disturbance of forest soils during logging. Increased erosion has been shown to result in decreased egg-to-fry survival of salmonids, decreased aquatic insect production, and in extreme cases, the filling of pools. Past logging activities have removed the riparian forest along over 90% of the streams located on state and private forest lands. This removal has resulted in a deficit of large woody debris (LWD). The deficit can be expected to persist for decades or centuries due to the time required for riparian forests to recover to a mature condition. The deficit of LWD is thought to be particularly important in determining coho salmon production. Coho fry densities in streams have been shown to be closely correlated with the amount of LWD found in stream channels (Murphy et al. 1985; Bjornn and Reiser 1991).

Logging activities are also suspected of affecting stream flows, particularly in portions of a watershed subject to periodic snow accumulations. High rainfall on these snow accumulations can cause stream peak discharges to increase, resulting in channel erosion, destruction of habitat, and mortality of

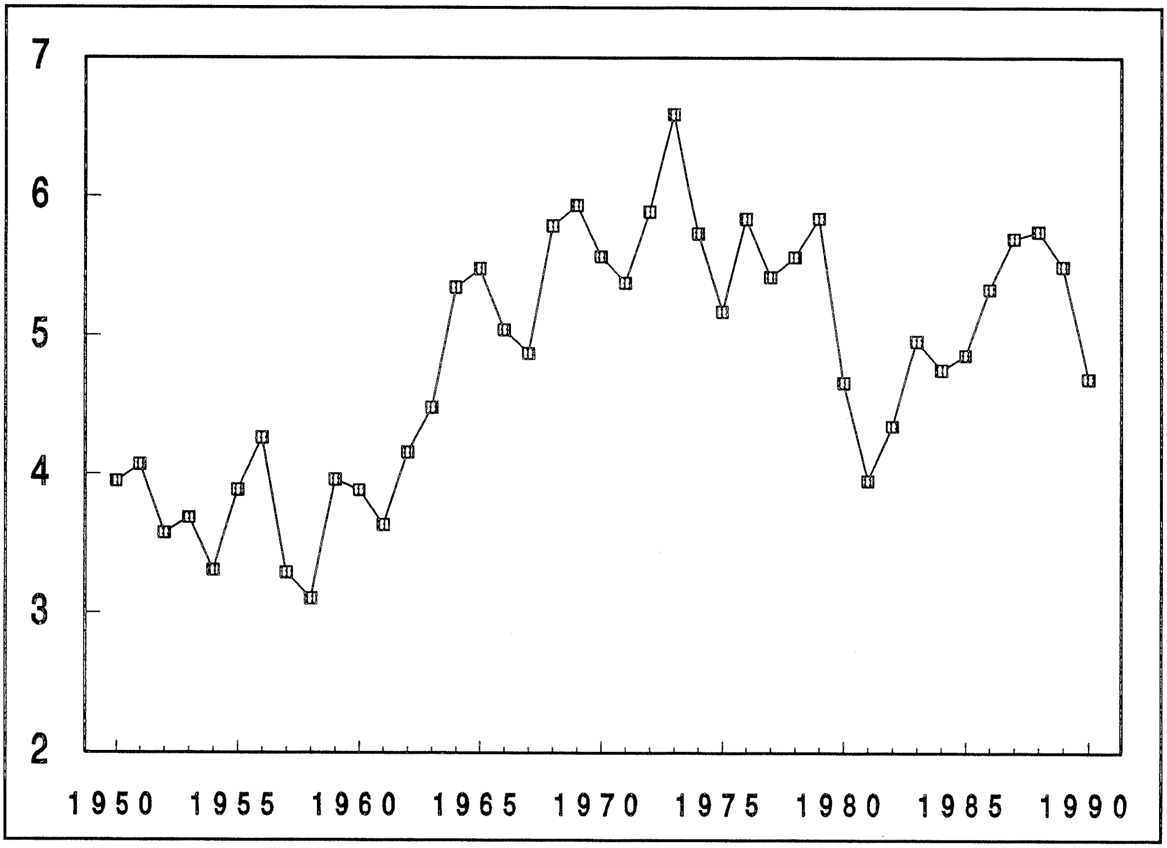

Figure 2.4. Trend in Washington State timber harvest (billion board feet) 1950-1990. (WDNR 1988).

overwintering fish (Chamberlin et al. 1991).

2.2.6 MANAGEMENT OF HABITAT

Management of fisheries habitat and land uses which can affect habitat, is split among a multitude of local, state, federal, and tribal agencies (Table 2.5). None of these agencies has the expressed primary responsibility to protect and manage fish habitat, although a number of agencies are required to consider habitat in their management decisions.

There are currently no programs for widespread ongoing monitoring and evaluation of fisheries habitat within Washington state. Sporadic and local efforts do occur. Examples of these programs are the Snohomish County Stream Team habitat mapping project, and U.S. Forest Service habitat monitoring. These efforts often use differing monitoring protocols and are not coordinated between agencies in order to develop comprehensive evaluations within a basin or watershed. As a result, existing habitat information is difficult to use for documenting or determining changes in habitat quality.

Table 2.5. **Partial list of agencies, permit processes, and responsibilities for some aspect of habitat management.**

Agency	Authority/Permit Process	Responsibilities
Federal		
U.S Fish and Wildlife Service	-Endangered Species Certification -NEPA -CWA Section 10 and 404 review	Comment on permits issued by other federal agencies
U.S. Forest Service	-NEPA -NFMA	Comply with federal regulations, manage federal forest and rangelands for multiple uses.
Bureau of Land Management	-NEPA	Consider impacts to fish habitat
Federal Energy Regulatory Commission	-Federal Power Act -Electric Consumers Protection Act	Consider impacts to fish habitat
NOAA/NMFS	-Endangered Species Certification	Comment on permits issued by other federal agencies
Soil Conservation Service		Consider impacts to fish habitat
Environmental Protection Agency	-NEPA -CWA	Protect water quality, consider impacts to fisheries resources.
U.S. Army Corps of Engineers	-CWA sections 10 and 404 -NEPA	Consider impacts to fish habitat
State		
Department of Ecology	-Shoreline Management Act -SEPA -CWA -Surface Water Code	Consider impacts to fish and habitat and water quality from permitted activities. Protect public interest. Establish minimum stream flows. Water quality compliance enforcement.

Department of Fisheries	-Hydraulics Code	Protect habitat from projects within stream high water marks and in marine waters of the state. Comment on permits issued by other agencies.
Department of Wildlife	-Hydraulics Code	Protect habitat from projects within stream high water marks and in marine waters of the state. Comment on permits issued by other agencies.
Department of Natural Resources	-Forest Practices Act -SEPA	Protect public resources. Consider impacts to fish habitat.
Local		
Cities	-Shoreline Management Act, SEPA, and various ordinances and policies.	Consider impacts to fish habitat.
Counties	-Shoreline Management Act, SEPA, and various ordinances and policies.	Consider impacts to fish habitat.
Tribal		
Tribes	-NEPA and other federal regulations. -Tribal regulations -Boldt Phase II	Responsible for management of reservations lands and waters, and protection of on and off reservation treaty reserved resources.

2.2.7 MARINE MAMMALS

Although not directly related to freshwater habitat or land-use, there has been speculation that marine mammal populations, particularly of the California sea lion and the harbor seal within Puget Sound and coastal waters are increasing, and that these increases may be responsible for declines in some salmonid stocks. This concern is not a recent one:

> It is conceded that salmon fishing in the Northwest is not what it once was. But have we considered that the very existence of the "silver hordes" is being jeopardized (1) by irrigation interests at the headwaters of the spawning streams; (2) by hydroelectric structures in the courses of these same streams; (3) by lumbering operations that pollute the rivers and reduce their flow a certain critical seasons; (4) by natural enemies at the entrances to these streams from the sea; and (5) by the prodigal wastefulness of the fishing industry itself in exploiting a gift of nature? In this

> final consideration, it appears that the seal and sea lion have fared ill, as being the most convenient scapegoats. (Scheffer 1928)

Data regarding the populations of sea lions and seals are very limited. Extensive hunting and slaughter of seals and sea lions was conducted from the 1930s until the early 1960s. Scheffer estimated the 1944 sea lion population within Washington state waters as approximately 500. This compares to an estimated historic population of approximately 10,000 (Scheffer 1928). Current numbers are thought to be somewhat below the historic figure, however according to NOAA personnel, a full census has not been conducted.

Further assessment of the impact of marine mammals on salmon stocks is needed. However, the extensive marine mammal eradication program does not appear to have resulted in any increase of salmon abundance. It seems unlikely that marine mammal populations are a major determinant of salmonid abundance. In some areas where fish are artificially confined, such as at the Ballard Locks in Seattle, predation may contribute to depletion of stocks which are already in low abundance. This type of situation has not been documented within the Snohomish, Stillaguamish, and Skagit Rivers or the Hood Canal system. Marine mammals are also known to remove fish from gill nets. This problem is quite severe in some locations.

2.2.8 DISCUSSION

Land use within the Snohomish, Stillaguamish, and Skagit rivers and Hood Canal have drastically altered historic habitat conditions. Table 2.6 summarizes the level of impact on each system. These impact levels represent a subjective assessment of the relative level of disturbance from each land use. No quantitative assessment of system wide impacts for any of these systems has been made by fisheries or land management agencies.

Increasing population growth in Washington is currently accompanied by increased land use activities which are known to impact fish habitat. Although no direct measurements of habitat quality and quantity are available, the increase in population and land use is coincident with declining production of salmon stocks. Evaluations of efficacy of regulations intended to reduce impacts from land use on fish habitat also appear to be very limited and were not evaluated for this report.

Expected future trends of population growth indicate that impacts to habitat will continue to increase due to upland residential and commercial developments. Water withdrawals for personal, agricultural, and commercial consumption will also increase with population growth. Although regulations to protect "sensitive" fish habitat areas are required under the new Growth Management Act, substantial variability in the strength of these regulations exists between counties and other local governments. In addition, a very strong private property rights movement exists within Washington. This movement threatens to weaken or eliminate existing or new aquatic protection measures.

Table 2.6. Subjective assessment of land use affecting freshwater salmon habitat within the systems of interest.

Land Use	Snohomish	Stillaguamish	Skagit	Hood Canal
Agriculture	H	H	H	M
Estuary Loss	H	H	H	M
Flood control	H	H	H	H
Forestry	M	H	H	H
Hydroelectric	L	L	H	M
Industry	L	L	L	L
M&I water	L	L	L	M
Shoreline development	H	M	M	M
Urbanization	H	M	M	M

H = High Impact M = Moderate Impact L = Low Impact

Wetland protection regulations are currently being debated at the national and state levels. Existing regulations do not prohibit filling, diking, or draining of wetlands. Although most large scale wetland losses occurred early in this century, wetlands are still being incrementally lost to a multitude of land use projects which each affect small wetland areas. There is currently no standard method for identifying and evaluating wetland ecological values or functions. It can be expected that incremental losses of these important habitats will continue to be lost in the foreseeable future.

Forest practices on federal lands are likely to decline in the short term due to restrictions designed to protect wilderness and sensitive or threatened species. Forest practices on private lands will likely decrease due to conversion on forest lands to other uses. Harvest on state lands will likely remain relatively stable.

New forest practice regulations in place since 1989 require riparian forests to be only partially harvested. These regulations should result in the long term increase of woody debris to stream channels, however, past clearcutting activities on almost 100% of state and private forest lands has resulted in the conversion of many riparian forest stands to deciduous tree species. Succession back to conifer dominated riparian stands could take several hundred years. Impacts of timber harvest on hillslope and stream channel erosion is likely to diminish under new state regulations, however erosion rates are likely to remain higher than historic background rates.

The fragmented nature of habitat regulation contributes to the continued decline in habitat quality. No agency has both the authority and the mandate to protect fisheries habitat from land use activities. Agencies which manage land use or habitat related issues such as water quality, are not directly and clearly mandated to protect habitat. Most of these agencies have some responsibility to consider impacts to habitat, but are required to balance these concerns with other human values and benefits. Impact to habitat, which are difficult to quantify and evaluate, are often assessed against economic considerations which may be quantified in terms of monetary value.

2.3 SNOHOMISH SYSTEM

2.3.1 INTRODUCTION

The Snohomish River system, which includes the Snohomish, Skykomish and Snoqualmie rivers, drains over 1,780 square miles of area. It contributes the second largest tributary inflow to Puget Sound. The river produces chinook, coho, chum, and pink salmon and steelhead. It is one of three river systems in the Puget Sound region still managed primarily for natural production of all anadromous species.

Anadromous fish habitats within the Snohomish River Basin have been greatly impacted by human and natural disturbance during the past 120 years. Many of the most significant human caused changes to the river system occurred early in this period. Many of the effects of the early modifications persist and in some cases, have not yet been completely manifest. Although more recent modifications of the river are less dramatic than past changes, they are occurring at a much higher frequency and rate. It is likely, given current human growth and development patterns in the Puget Sound basin, that future impacts to the basin will continue to grow in intensity.

2.3.2 AGRICULTURE

Historically, the Snohomish had an extensive estuary wetland complex which extended from the mouth of the river near the City of Everett, to R.M. 13 near the town of Snohomish. This estuary contained a number of freshwater and brackish sloughs. Beginning in the late 1800s, continuing into the early 1900s, 80% of this estuary wetland complex was diked and drained for use as agricultural land. Virtually all of this area is still diked, although there have been some recent efforts to return some of this area to wetland status.

Farming on the converted wetlands include primarily dairy operations and strawberry farming near the city of Marysville. Water quality in many of the sloughs and small tributaries has been severely degraded in these agricultural areas by animal wastes and pesticide residues. In addition, access by anadromous fish to many small channels has been eliminated due to dikes, or restricted by tide gates.

2.3.3 INDUSTRY

The lower river was also extensively modified near the turn of the century in order to improve navigation and moorage for the City and Port of Everett. The main channel of the Snohomish was diverted by a series of training walls, dredging, and the construction of a permanent island (Jetty Island) which directs the flow of the river along the shore by the City of Everett. This redirection of the river is maintained by periodic dredging by the U.S. Army Corps of Engineers. The change also enabled deep water moorage at the Port of Everett, resulting in early industrial development of the area.

Industrial development was associated with extensive discharge of pollutants to the mouth of the Snohomish River. Recent studies have identified extensive pollution of sediments in and around the Everett Harbor area despite decreasing industrial activities.

Many of the intertidal lands which remain at the mouth of the Snohomish river have been used extensively for log storage. Log storage impacts intertidal salmonid habitat by disturbing bottom sediments and communities, and by depositing large amounts of bark. These deposits decrease dissolved oxygen concentrations and leach lignin into the water column. Bottom disturbance, reduced oxygen, and lignin have been shown to reduce benthic invertebrate populations which are a major source of food to juvenile salmonids. Above the estuary, extensive modifications of the river's flood plain, tributaries and upland areas have also occurred.

The flood plains of the Skykomish and Snoqualmie rivers have been extensively diked. Most of the flood plain areas are used for agriculture although several towns and some residential development has occurred. Recent water quality studies conducted by the Tulalip Tribes have shown continuing degradation of water quality, particularly within the Snoqualmie river, by dairy and other agricultural activities. Water quality problems are particularly severe in small tributary streams.

2.3.4 FLOOD CONTROL

Historic flood control activities within the basin includes periodic dredging of portions of the rivers and maintenance of dikes. Dikes have disassociated many flood plain oxbows and sloughs from the main channel. Dikes have caused concentration of stream flow during storm events and have resulted in armoring and scour of stream bottom material, most notably in the Raging River, the Pilchuck River, and the Snoqualmie river near the Town of Carnation. In addition, most streamside vegetation and in-channel cover has been eliminated to promote the rapid discharge of storm flows. This has resulted in a loss of most fish refuge areas in the Snoqualmie river, the Pilchuck River, and portions of the Skykomish river. Tributary streams have also been extensively cleared of debris in order to facilitate storm discharges and reduce bank erosion.

2.3.5 URBANIZATION

Many areas within the basin have been urbanized or developed for residential use. The cities of Marysville, Snohomish, Monroe, Sultan, Skykomish, Duvall, Carnation, and North Bend all discharge treated and chlorinated sewage effluent to the river system. The effects of these discharges on salmon are not known although benthic communities below sewage outfalls have been shown to consist of species not normally used or available to salmonids for food. Increasing urbanization has also resulted in localized impacts to tributary streams from high surface runoff. Impacts are especially noticeable in the Quilceda creek system which flows through the City of Marysville and the City of Arlington.

Agriculture, flood control, and urbanization have all resulted in loss or detachment of associated wetlands which are used by salmonids for summer and winter rearing. These wetlands were particularly abundant and common along mainstream and tributary channels flowing through wide alluviated valleys such as found throughout the Snohomish River system. Summer and winter rearing space has been found to be a major determinant of coho salmon production (Zillges 1977). Loss of these wetlands also reduces water storage which formerly was important in supplementing summer low flows, resulting in low flow decreases, particularly in many small tributary streams.

2.3.6 GRAVEL MINING

Many parts of the Snohomish system, most notably the Pilchuck River and the Skykomish River, have been used for instream gravel mining operations. These operations have reduced the transport and supply of spawning gravel within the system. While operation restrictions have been placed on these operations, violations of permit conditions have resulted in direct impacts to fish. These impacts include stranding of juvenile salmonids in excavated areas, blockage of access to tributary streams, and direct disturbance of spawning areas.

2.3.7 FORESTRY

Logging within the Snohomish river basin has been extensive. Approximately 2/3 of the basin flows through non-federally owned land. Virtually 100% of these non-federal lands have been logged at least once during the past 100 years. Many areas have been logged twice and some areas are now experiencing their third harvest. Until 1989, there was no requirement for leaving vegetative buffer strips along rivers and streams. This has resulted in a long term deficit of large woody debris to stream channels. Salmon production, particularly for coho, has been shown to be directly related to abundance of woody debris (Murphy et al. 1985). In addition to the loss of the source of woody debris, many streams were splash dammed or cleared of debris following logging. Until recently, the importance of this material was not recognized and it was removed to reduce erosion and eliminate fish passage problems. Debris remaining in the channel is subject to natural decomposition. For the large portions of the basin which were logged beginning over 100 years ago, LWD remaining in stream channels from pre-logging periods has been almost entirely lost to natural decomposition and mechanical removal. Areas which were harvested more recently may have some residual wood, however it is likely that most of this will be gone within the next few years. Lack of buffer strips has also resulted in increases in water temperatures, particularly in lowland streams.

Logging has also resulted in extensive erosion in some areas. Of particular note are the Pilchuck River, Woods Creek, Beckler River, North Fork Skykomish, North Fork Tolt River, Raging River, and the South Fork Snoqualmie River. It is likely that severe local erosion occurred during logging of many other streams, particularly before modern logging techniques made partial or full suspension of logs possible. Extensive logging road systems have been constructed throughout the basin. These roads represent a long term source of erosion and hillslope failure.

2.3.8 OUT OF STREAM WATER USE

Water supply reservoirs have been constructed on two major tributaries to the Snohomish system. The City of Everett constructed a water diversion dam on the Sultan River in 1911, permanently blocking access by anadromous fish to over twenty miles of river and tributary habitat. In addition, prior to 1964, numerous instream flow violations occurred during summer low flow periods resulting in dewatering of the Sultan River. An instream flow restriction is now in place on the river and an upstream storage reservoir has resulted in consistent maintenance of summer flows. In addition to instream flow impacts, the Sultan storage reservoir appears to be creating a large volume spring which is introducing large amounts of clay and fine sediment to the Pilchuck River.

The City of Seattle maintains a water supply reservoir on the South Fork Tolt River. This reservoir is located above the historic anadromous fish zone so it does not directly block access to any habitat. However, the reservoir is the possible cause of two large earth failures just downstream of the dam which introduced tens of thousands of cubic yards of sediment to the S.F. Tolt in the 1960s and 1970s. The slide has currently stabilized. The reservoir may also be blocking sediment transport within the Tolt system. This is particularly important because the Tolt river is the only source of gravel to a very significant salmon spawning area within the mainstem Snoqualmie River.

Instream flows within the Tolt are protected by a minimum flow requirement, however increasing water demand within the City of Seattle is expected to result in an increasing frequency of critical minimum flow releases. Critical minimum flows, which are released to the river during low water years, are not designed to be sufficient to maintain large populations of anadromous fish.

2.3.9 RECENT AND FUTURE IMPACTS

Many of the major modifications to Snohomish habitat occurred early in the century, however many continue today. Requirements for retaining vegetative buffers along stream channels following logging were not implemented until 1989. Existing buffer regulations require a partial leave of representative vegetation. Since most areas have been harvested at least once, most riparian forests now consist of deciduous or herbaceous species which will not provide quality large organic debris. Periodic re-entry into these riparian zones may tend to promote these species resulting in permanent deficits in large coniferous trees along streams and rivers.

Current forest management economics indicate future timber harvest rotation will be approximately every 45 - 60 years. This length rotation will result in logging of private and state forest lands at twice the rate experienced during the past century. It is likely that future impacts associated with logging, particularly hillslope and road erosion, will increase in magnitude and frequency relative to past impacts.

Urbanization, and associated losses of wetlands, increases in storm runoff, decreases in summer low flows, and increased public pressure for increased flood control is likely to continue within the Snohomish River system. Areas of high growth include Marysville, Arlington, Monroe, the Snoqualmie valley, and North Bend.

Development of small scale/high head hydroelectric projects is likely to increase in the future. During the mid-1980s, federal permit applications were submitted for over 120 small-hydro sites within the Snohomish basin. Future increases in energy prices are likely to make development of many of these sites economically feasible. Many of these projects can be located above the anadromous fish zone, however they may have long term effects on instream flow fluctuations, sediment transport, and hillslope stability which may effect anadromous fish habitats.

Increased human population in the region is likely to result in increased water supply demands. The City of Seattle is currently planning for development of the North Fork Tolt River within the next ten years. It is uncertain at this time whether sufficient discharge for both water supply and fisheries needs exists in the North Fork. An impoundment will affect gravel transport and recruitment within the Tolt and mainstem Snoqualmie River.

2.3.10 PROFILES OF SPECIFIC SNOHOMISH RIVER HABITATS AREAS

Reach specific descriptions of habitat in the Snohomish River is not available at this time.

2.3.11 RECOMMENDATIONS

- *Acquire and/or re-establish hydraulic connection between flood plain, side channels, and main stem river.*
- *Restore coho habitat through artificial and natural replacement of large woody debris throughout the system.*
- *Develop regulatory standards to minimize future erosion from sensitive geologic areas.*
- *Establish a inventory and monitoring process within the river, including those areas outside USFS ownership.*
- *Establish watershed habitat management plan or management coordinating body.*

2.4 STILLAGUAMISH SYSTEM

2.4.1 INTRODUCTION

The Stillaguamish River system has a drainage area of over 800 sq. miles and contains over 975 miles of river and stream habitat. The system produces coho, chinook, pink, and chum salmon as well as steelhead. Along with the Snohomish and Skagit rivers, the Stillaguamish is one of the three rivers managed primarily for natural production of all anadromous species.

Like the Snohomish and Skagit River systems, the Stillaguamish has been greatly altered by human activities.

2.4.2 AGRICULTURE

As with most other Puget Sound river basins, extensive alteration of the Stillaguamish flood plain, estuary, and associated wetlands has occurred. Approximately 90%+ of the lower estuary and associated wetlands have been diked and converted to agricultural uses. This has resulted in an extensive loss of rearing area for juvenile salmonids.

Diking of the flood plain has also occurred throughout the mainstem, North Fork, and South Fork Stillaguamish river valleys. Many off channel and tributary habitats are no longer accessible to salmonids, or have been highly altered by agriculture. Most lowland streams have been channelized, cleaned of debris, and have little riparian vegetation. Associated wetlands have been filled or are no longer connected to the stream channels by surface channels. Water quality in the lower Stillaguamish river is also poor, particularly during summer low flow periods, due to non-point pollution from dairy and seed crop operations.

2.4.3 URBANIZATION

Urbanization of Stanwood and Arlington areas is also affecting habitat. Several tributaries which historically supported anadromous fish have been repeatedly polluted by canning operations at Stanwood. Flood control dikes have also been constructed to protect Stanwood, resulting in fish access problems to several tributary streams. Residential and commercial development around the Arlington area has resulted in impacts to many small tributary streams in this area. Impacts include loss of associated wetland rearing areas, increases in storm flow run-off, clearing of beneficial woody debris from stream channels, and loss of riparian vegetation.

2.4.4 FORESTRY

Logging has occurred throughout the Stillaguamish basin. Virtually all private and state forest lands, and many federal lands, have been logged one or more times. The glacial geology of the Stillaguamish basin makes it particularly prone to surface and deep seated erosion following logging and road building. Logging activities are directly responsible for major losses of habitat in the Stillaguamish system. Of particular note are Deer Creek (trib. to N.F.), the upper North Fork, Canyon Creek (tributary to S.F.), and the mainstem of both the North Fork and South Fork. Water quality throughout the system is poor due to high sediment loads caused by numerous landslides and road failures. Major slides have occurred at Oso (North Fork, 1960s), Deer Creek (1980s), and at Gold Basin (South Fork, 1950s)

2.4.5 GRAVEL MINING

Gravel mining operations have also occurred within the Stillaguamish, particularly in the mainstem and lower portions of the North and South Forks.

2.4.6 OUT OF STREAM WATER USE

No major water storage dams have been constructed within the Stillaguamish river system. However, numerous withdrawals from tributaries and the mainstem are made by direct pumping or from wells immediately adjacent to the stream. No quantification of these withdrawals has been made and monitoring is not conducted. The Stillaguamish currently has no minimum flows established and an ongoing study being performed by the Stillaguamish Tribe and the Bureau of Indian Affairs indicates that existing water rights for out of stream uses exceeds average low summer flow by several times (pers. com. Pat Stevenson, Stillaguamish Tribe Natural Resources Dept.).

Natural characteristics of the watershed make the Stillaguamish susceptible to low summer flows and drought. The headwaters of the basin do not extend deeply into the Cascade mountains and the basin receives a relatively low portion it's annual precipitation in the form of snow. As a result, the basin is more susceptible to low snowfall years than other adjacent Puget Sound watersheds such as the Skagit and Snohomish. This situation also make the anadromous fish very susceptible to impacts caused by out of stream water uses.

2.4.7 HYDROELECTRIC

No significant hydroelectric development has occurred within the Stillaguamish basin.

2.4.8 RECENT AND FUTURE IMPACTS

The Stillaguamish River is likely to continue to be impacted heavily by logging activities. Future rotations on private and state lands are expected to every 45 - 60 years. This is approximately twice the rate experienced historically. Past logging has resulted in many large and small landslides which will continue to introduce sediments to the river system. Future logging is likely to result in further sediment increases. Riparian zones are also heavily modified due to past practices and many streams do not have a source of high quality large woody debris.

The Stillaguamish River system below approximately elevation 1600 feet is heavily influenced by past glaciation. Extensive deposits of glacial till and lacustrine deposits make the basin extremely prone to erosion and mass wasting. Major landslides on the South Fork (Gold Basin Slide), and on the North Fork (Deforest Creek and Oso Slides) have severely affected the mainstem river. Numerous smaller events located on tributary streams have also occurred. While much of the lower basin was logged for the first time many years ago, it is primarily since the 1960s that the steeper more inaccessible headwater tributaries have been harvested. This recent logging has resulted in recent major disturbances to non-mainstem habitats. It is likely that coho and steelhead have been affected disproportionately by these more recent events.

Urbanization is expected to continue in the Arlington, Stanwood, Granite Falls, and Darrington areas. Granite Falls is currently proposing annexing areas which would more than quadruple the cities size. Urban development will result in further losses of associated wetland rearing areas, increased storm water runoff, increased demand for flood control, increased sewage discharges, and modification of many small tributary streams.

Water withdrawals will continue to reduce summer flows, and therefore reduce coho summer rearing habitat, since no minimum instream flows have been established for the Stillaguamish river system. Increasing urban and sub-urban development will likely increase demands for water.

Large areas, particularly in the estuary and flood plain, are expected to remain in agricultural use.

2.4.9 PROFILES OF SPECIFIC STILLAGUAMISH RIVER HABITAT AREAS

2.4.9.1 Mainstem and Tributaries

Length: 18 miles mainstem, 12 miles side channels, 68 miles of tributaries
Major Tributaries: (13) including Church Cr., Armstrong Cr., Pilchuck Cr., and Portage Cr..
Land ownership: Private
Major Land Uses: Agriculture, urban, rural and residential, forestry.

The mainstem Stillaguamish and tributaries have been heavily influenced by agriculture and associated diking, dredging, development of the flood plain, rural and urban water withdrawals, and in-channel gravel mining.

Sections of the river and tributaries have very poor water quality. This is primarily associated with dairy and other agricultural land uses. The water quality in the mainstem is also impacted by turbidity and high sediment load delivered from natural and logging related sources in the North and South Forks. High summer water temperatures and low summer flows also reduce the habitat quality within the mainstem and lower portions of the tributaries.

Riparian cover is poor in most areas of the mainstem and lower tributaries. Many side channels in the lower river have been isolated from the main channel, reducing off-channel habitat availability.

2.4.9.2 Lower North Fork and Tributaries (below Oso)

Length: 14.5 miles mainstem, 63 miles of tributaries
Major Tributaries: (16) including Grant, Rock, and Elk Creeks, excluding Deer Creek, remainder unnamed.
Land ownership: Private, WDNR
Major Land Uses: Agriculture, forestry.

The North Fork below Oso has been impacted primarily from agriculture within the flood plain and forestry above the flood plain. Rural and residential development is increasing however. Substantial lengths of the mainstem have been diked and/or rip-rapped. However, this portion of the river supports chinook and pink salmon spawning and the tributaries also support coho salmon.

Water quality in this portion of the basin is higher than that found in the lower Stillaguamish. However, this portion of the river is affected by high sediment loads delivered from Deer Creek and recent landslides along the upper North Fork Stillaguamish. This section of the river has also been impacted in the past from a major landslide upstream at Hazel which occurred in the 1960s.

Tributaries have been affected primarily by forestry activities although many have been modified by agriculture in their lower portions. This area was first logged around the turn of the century. Many tributaries were cleaned or used to transport logs and all old growth riparian forest was removed. As a result, there is a long term deficit of large woody debris in these channels, reducing coho habitat quality and quantity.

Many side channels and off-channel ponds have been isolated from the main channel and tributaries, further reducing coho habitat.

2.4.9.3 Deer Creek

Length: 24 miles mainstem, 56 miles of tributaries
Major Tributaries: Higgins, Deforest, and Little Deer Creeks
Land ownership: WDNR, private, and USFS
Major Land Uses: Forestry

Deer Creek has been severely degraded by forestry activities. Over 2/3 of the basin has been logged, with only portions of old growth forest remaining on USFS lands located in the upper 1/3 of the watershed. Some limited agricultural related impacts occur in the lower mile of the stream.

Water quality in Deer Creek is poor with summer temperatures exceeding 75° F. Turbidity and sediment levels are very high. Sediment is being deliver to the stream from a large landslide at Deforest Creek as well as numerous smaller deep seated and shallow landslides and road failures throughout the basin. The deep and extensive glacial and lacustrine deposits within the basin make it extremely sensitive to forestry activities. This stream was described in 1911 by Zane Gray as one of the most beautiful mountain trout streams he had seen. This description would not apply today.

Riparian vegetation in the lower 2/3 of the basin is poor, in part because of past logging without provision for riparian leave areas and in part because of channel migration caused by the extreme sediment load within the stream. Levels of large organic debris are probably very low compared to historical levels. Off-channel coho rearing seems very limited although a survey has not been conducted.

Some rehabilitation efforts have been conducted within Deer Creek and the USFS has temporarily closed their lands to further logging. Limited logging is occurring on state and private lands. Monitoring of fish populations and water quality has been conducted over the past 10 years.

This stream was historically used by winter and summer steelhead and coho salmon. Populations of these species are currently extremely low or non-existent. The recent monitoring has shown a severe decline in all species within the basin.

2.4.9.4 North Fork - Hazel area

Length: 14 miles mainstem, 86 miles of tributaries
Major Tributaries: French, Montague, Dicks, Rollins, and Brooks creek and Boulder river.
Land ownership: Private, WDNR, USFS
Major Land Uses: Agriculture, rural residential, forestry.

The flood plain and lower ends of the tributaries have been impacted mostly from agriculture and past logging activities. Tributaries reaches above the flood plain have been primarily affected by logging activities. The upper end of the Boulder river has not been logged and is now in wilderness status.

Major erosion has occurred recently on Rollins, Montague, and Brooks creek. This erosion is associated with forestry, road construction, and natural unstable deposits. The major slide at Hazel is currently relatively stable and not considered a current impact on the mainstem. Suspended and bedload sediment is being delivered to the mainstem from upstream sources within the headwaters of the North Fork. Despite sediment inputs, water quality in this area is considered good.

The flood plain and lower portions of the tributaries were logged at the turn of the century resulting in low levels of large organic debris and highly altered riparian zones. Although a survey has not been conducted, it can be assumed that coho habitat in the tributaries has been degraded. A number of side channels and ponds have been isolated from the main channel, reducing coho off-channel rearing area.

This portion of the river is used by chinook, coho, chum, pink, and steelhead.

2.4.9.5 North Fork Headwaters

Length: 20 miles mainstem, 90 miles of tributaries
Major Tributaries: include North, Middle, and South branches, and Squire, Segelson, and Crevice creek.
Land ownership: Private, USFS
Major Land Uses: Forestry, some agriculture, rural residential.

This area contains good water quality and fairly high quality fish habitat. Lower ends of tributaries have been modified by past logging of riparian zones and stream cleanout. However, some high quality habitats remain.

Recent erosion along the North Fork has occurred and is associated with forestry activities. The magnitude and extent of this erosion are not known. Levels of sediment appear to be lower than those in downstream areas within the basin but localized impacts to mainstem and tributary habitat are likely occurring.

2.4.9.6 South Fork below Granite Falls

Length: 18 miles mainstem, 145 miles of tributaries
Major Tributaries: include Jim, Canyon, and Jordan creeks
Land ownership: Private, USFS within upper 1/2 of Canyon creek
Major Land Uses: Agriculture, rural residential, forestry, urban (Arlington and Granite Falls).

The flood plain of the lower South Fork has been extensively altered by diking, rip-rapping, agriculture, and past logging activities. Lower portions of the tributaries have also been affected.

Water quality in the mainstem is impacted by delivery of sediment from Canyon Creek, the Gold Basin slide on the upper South Fork, and from natural and forestry related sources in the upper South Fork basin. High levels of sediment probably resulted in severe declines in pink salmon populations in the 1950s, however recent production seems to be increasing.

Off-channel ponds and rearing areas, particularly in the Arlington area, have been isolated from the main river and have reduced coho production potential from historic levels. Logging along stream channels since the turn of the century has greatly modified riparian forests, and it is likely that LWD levels are low in most tributaries.

The Jim Creek drainage has also been affected by a military installation at it's headwaters. This installation has channelized the stream and keeps the headwater basin denuded of vegetation. Water quality within Jim Creek is good however.

2.4.9.7 South Fork above Granite Falls

Length: 35 miles mainstem, 107 miles of tributaries
Major Tributaries: Numerous
Land ownership: Private, USFS
Major Land Uses: Forestry, rural residential

The upper South Fork Stillaguamish river was made accessible to salmon and steelhead by the construction of a fish ladder in 1954. Access to the upper river has been blocked several times by landslides within the canyon above the falls.

Forestry is the dominant land use. The area below Verlot is primarily privately owned and has been logged one or more times. Past logging has likely resulted in modification of riparian vegetation and a deficit of large woody debris in stream channels. No surveys have been conducted outside USFS ownership.

Above Verlot, the primary landowner is the USFS, although some lands are privately held, particularly at the former town site of Silverton. Logging occurred along the main river channel in the late 1800s and early 1900s. The area was served by rail in order to access the mining town of Monte Cristo. Evidence of early logging can also be found extending up many of the tributaries.

A major landslide occurred along the main South Fork channel in the 1950s. This landslide is still active, producing large quantities of suspended and bedload sediments. Many tributaries have also been degraded by erosion associated with natural causes and forestry related disturbances. As previously discussed, the basin below 1600 feet elevation is dominated by glacial and lacustrine deposits which are highly susceptible to disturbance.

Above the Gold Basin slide, water quality is generally good to excellent.

The area is used by chinook, coho and steelhead. Coho habitat is good although the poor access through the Granite Falls fish ladder and the canyon immediately upstream of the ladder may be limiting production.

2.4.9.8 Canyon Creek

Length: 20 miles mainstem, 47 miles of tributaries
Major Tributaries: North Fork and South Fork.
Land ownership: Private, USFS
Major Land Uses: Forestry

Impacts to Canyon Creek are largely associated with forestry. Complete logging of the lower 1/2 of the basin has resulted in an number of hillslope and road failures and associated deep and shallow land sliding. Harvest of riparian forest has also resulted in modification of channels and a probable long term deficit of large woody debris in the lower 1/2 of the basin. Logging of second and third growth timber is continuing in this area.

The upper 1/2 of the basin is within USFS ownership and has also been extensively logged. Numerous road failures have occurred and the stream is currently considered in an unacceptable condition by the current forest plan. Logging activities on USFS lands have been greatly reduced from historic levels.

Water quality, with the exception of bedload sediment levels, can be considered good in this system.

Canyon Creek is used by chinook, coho, and steelhead. A known historic run of summer chinook is no longer present. Off-channel rearing opportunities for coho are limited within USFS lands. A survey has not been conducted on private forest lands.

2.4.10 RECOMMENDATIONS

- ***Establish and secure minimum instream flows for the Stillaguamish river system.***
- ***Acquire and/or re-establish hydraulic connection between flood plain, side channels, and main stem river.***

- ***Restore coho habitat through artificial and natural replacement of large woody debris throughout the system.***

- ***Develop regulatory standards to minimize future erosion from sensitive geologic areas.***

- ***Improve fish passage at Granite Falls and in canyon above the falls.***

- ***Establish a inventory and monitoring process within the river, including those areas outside USFS ownership.***

- ***Establish watershed habitat management plan or management coordinating body.***

2.5 SKAGIT SYSTEM

2.5.1 INTRODUCTION

The Skagit River basin is the largest of the Puget Sound drainages. Within its over 3,000 square miles are extensive anadromous fish habitats. Many areas of the basin however have been significantly modified by human activities over the past 150 years. Primary land uses include agriculture, forestry, urban, rural residential, and hydroelectric development.

2.5.2 AGRICULTURE

Agriculture within the lower Skagit system and throughout all flood plain areas has caused extensive modification of salmonid habitat. Early clearing of land, diking, and draining has resulted in loss of habitat diversity, almost total loss of large organic debris, elimination of riparian vegetation, and water quality degradation. Many smaller tributaries have been extensively dredged and straightened, severely reducing coho habitat quality and quantity. Extensive application of fertilizers and pesticides affect water quality in the lower basin.

2.5.3 FLOOD CONTROL

Virtually the entire river below R.M. 20 has been diked and rip-rapped for flood control purposes. This activity has resulted in the isolation of sloughs and side channels. It is estimated (SSC 1992) that over 40 miles of this type of habitat have been lost. Dikes and levees also reduce the productivity of mainstem river habitat by increasing the velocity and reducing the cover characteristics of the river. This appears to cause higher fish mortality during flood events through the elimination of refuge areas for small salmon.

Diking and dredging of tributaries has significantly reduced the production potential of the small tributaries by reducing habitat diversity and instream cover and by isolating off-channel rearing and refuge areas. The Skagit System Cooperative (SSC 1992) estimates that flood control measures have resulted in losses of approximately 300,000 coho smolts per year (Table 2.7). If this level of production could be replaced, we could reasonably anticipate meeting the full escapement goal; of 30,000 wild spawners on an annual basis, a doubling of the terminal area harvest, and the removal of Skagit wild coho from the current list of weak stocks that chronically limit PFMC and other preterminal fisheries. Skagit coho have been the primary limiting stock in 3 of the last 6 years. Had Skagit coho not been limiting in those years, ocean harvest quotas might have increased substantially depending on constraints imposed by other weak stocks. This lost production also results in lost fishing opportunity to Puget Sound preterminal coho fisheries and possibly to ocean chinook fisheries since restrictive coho quotas often limit chinook opportunity as well.

Table 2.7. Estimated annual losses of smolt production from flood control measures and direct loss of adult harvest at the terminal area fishery. (from SSC 1992).

Habitat Area	Lost Smolt Production	Loss to Terminal Area Fishery
Side Channel Sloughs	212,100	4,450
Distributary Sloughs	52,600	1,100
Tributaries	30,100	630
Tidal/Riverine	Unknown	Unknown
Mainstem	Unknown	Unknown
Estuary	Unknown	Unknown
Total	294,800 +	6,180 +

2.5.4 FORESTRY

Fish habitat of the Skagit river system has been extensively modified by forestry activities. As with other Puget Sound basins, lower elevation and flood plain areas were logged early in this century with no regard to habitat impacts. As a result, most channels have a deficit in large woody debris and highly modified riparian forests. Many channels were "cleaned" or used for splash damming, further impacting the channels and removing all or most of the original woody debris.

Recent logging has impacted higher elevation locations. Second and third harvests of lower elevation areas is also occurring. Logging of higher elevation areas has resulted in disturbance of lands more susceptible to erosion and mass wasting. Drainages such as Phinney Creek have recently been impacted by numerous road failures, landslides, and debris torrents.

2.5.5 HYDROELECTRIC

The mainstem Skagit River has three dams operated by Seattle City Light (SCL) located just upstream of the town of Newhalem (River Mile 95). These are complete blockages to anadromous fish. While historical evidence suggests that anadromous fish production upstream of these dams was minor, severe flow modifications to the Skagit River are experienced downstream of the dams. These fluctuations, due to manipulating the river for power management, has stranded many spawners, fry, and redds. A recent negotiated settlement between resource agencies, tribes, and SCL (May 1990) adopted a flow agreement that will greatly reduce these impacts. The remaining impacts that could not be mitigated through flows are planned to be mitigated through a combination of hatchery releases and habitat improvements. This part of the agreement has not yet been implemented.

The Baker River system, tributary to the Skagit near the town of Concrete, has two dams. This system potentially has significant sockeye and coho production. Coho escapements to the Baker, even after dam construction, were as large as 20,000, but more recently escapements have been in the hundreds (1979-83) and less than 2,000 for 1990 and 1991. Adults returning to spawn in the Baker River system must be trapped and hauled by truck upstream of the dams. Smolt outmigration efficiency is estimated to be 60% at the upper dam and 10% at the lower dam.

Other Skagit River tributaries are not free from hydroelectric impacts. Approximately 30 projects are seeking construction permits, but only 2 projects have been built and are operating to date. The direct impacts to anadromous include loss of flow; stranding of adults, redds, and fry; and blockage of anadromous habitat. Indirect impacts to anadromous fish habitat is primarily increased sedimentation due to the roads and pipelines constructed.

2.5.6 PROFILES OF SPECIFIC SKAGIT HABITAT AREAS

Reach specific descriptions of habitat within the Skagit River are not available at this time.

2.5.7 RECOMMENDATIONS

- ***Establish inventory and monitoring process within the river system.***
- ***Acquire and/or re-establish hydraulic connection between flood plain, side channels, and mainstem river.***
- ***Develop regulatory standards to minimize future erosion from sensitive geologic areas.***
- ***Establish and secure minimum instream flows for the Skagit system, especially in agricultural and urban areas.***
- ***Improve downstream passage at Baker Lake facilities.***
- ***Reduce incidence of landslide activities as a result of timber harvest activities.***

2.6 HOOD CANAL

2.6.1 INTRODUCTION

Currently, Hood Canal coho salmon are managed as an aggregate of stocks originating in several rivers and streams throughout the Hood Canal watershed. The myriad streams provide for a variety of habitat types. Human development, with varying degrees of intensity, is widespread across the watershed. Much of the freshwater habitat in Hood Canal has been extensively affected by past and present human activity. Impacts to coho salmon habitat from the developments and land use practices cover a wide range of activities including: hydroelectric projects and water diversions, logging and forest conversions, shoreline construction and watershed developments. The impacts from the activities are either direct or indirect and can be cumulative. Recent and projected rapid human population growth and concomitant land development will increase the cumulative impacts.

Presently, the most comprehensive view of the overall Hood Canal salmon habitat can be found in the Washington Department of Fisheries' (WDF) stream catalog (Williams et al. 1975). The catalog, however, was completed over seventeen years ago and little work has been conducted since to quantitatively assess the current status of coho salmon habitat in Hood Canal and the extent of recent developments and their impacts to freshwater habitat in Hood Canal.

2.6.2 HYDROELECTRIC PROJECTS AND WATER DIVERSIONS

Several Hood Canal drainages, which historically have been significant coho salmon production areas, have hydroelectric projects already in operation or projects that are being proposed. A significant proportion of Hood Canal wild coho salmon are produced in the Skokomish River system. The Cushman hydroelectric projects, located on the North Fork Skokomish River, were constructed around 1930. The projects diverted all of the flow of the North Fork approximately 17 miles upstream of the river mouth. The flow is diverted directly to Hood Canal just west of the mainstem river mouth. Some flow (30 CFS) has been restored since 1988 as a result of on-going hydroproject licensing proceedings, but still far short of the historical pre-project flows (approximately 950 CFS annual average flow). Significant amounts of salmon habitat have been lost as a result of the diversion. The impacts from the diversion are coupled with logging in the South Fork Skokomish River and diking and agricultural developments in the mainstem.

Other hydroelectric projects exist or are being proposed for several Hood Canal drainages. Lilliwaup Creek has a small scale hydroelectric development located just above impassable falls. Hydroelectric projects are being proposed for the Hamma Hamma River and the Dosewallips River, both located on the western side of Hood Canal.

Water diversion projects are also evident on the Tahuya River, in southern Hood Canal, and Big Beef Creek in northern Hood Canal. These diversions provide for the regulation of reservoir levels to enhance property values along the shorelines. Both of these dams have fishways, but once productive stream habitat is now inundated by reservoirs and slackwater. The Union River and the Little Quilcene River both have dams which provide storage for municipal water supplies. The impoundments contribute to low flows and high water temperatures primarily during the summer and fall months.

2.6.3 LOGGING AND FOREST CONVERSIONS

Logging and forest conversions are prevalent throughout the Hood Canal watershed. Extensive logging and road building has occurred in the Skokomish River drainage. Piecemeal logging and forest conversions are continuing on most of the west side streams and contribute to the problem of cumulative impacts. Kitsap County, on the east side of Hood Canal, is second only to King County in terms of population density (Table 2.1). Kitsap Peninsula streams experience continual forest lands conversions for residential and other human development. These streams have historically been significant coho salmon production areas. Logging, land conversion and large acreage subdivisions are the primary land use activities. Impacts have included increased storm water flows, landslides, stream bed sedimentation, and loss of riparian vegetation.

2.6.4 SHORELINE CONSTRUCTION AND WATERSHED DEVELOPMENTS

Shoreline and watershed developments have increased at an accelerated pace during the past few years. This trend is evident by the number of Hydraulic Project Approvals that have been applied for since

1989. The Washington Department of Fisheries figures show that 168 applications for bankline or shoreline structures in Hood Canal were sought in 1989, 134 in 1990, and increased to 415 in 1991. All of the counties that encompass the Hood Canal watershed are projected to exhibit significant growth over the next three years. It can be expected that even more watershed development will impact existing coho salmon habitat.

2.6.5 INSTITUTIONAL FACTORS AFFECTING HOOD CANAL COHO SALMON HABITAT

Politically, the Hood Canal watershed is within the jurisdiction of three counties, two Indian Tribes and several towns and other human population centers. Environmental regulatory authority throughout Hood Canal is subject to Federal, State, County and Tribal governance. To date, no regional authority or jurisdiction exists to manage the Hood Canal habitat in a comprehensive and cohesive manner.

Recent projections by the State of Washington's Office of Financial Management shows that between the years 1990 and 1995 the populations of Mason, Kitsap and Jefferson County will grow at rates ranging from ten to fifteen percent, with Kitsap County's population expected to double over the next twenty years. The rapid growth projected for the Hood Canal watershed will impact salmon habitat. Regulatory authorities will be required to develop a regional and comprehensive system for managing the growth and ensuring minimal impacts to existing habitat and provide for measures that can revitalize the productive capacity of Hood Canal salmon habitats.

2.6.6 PROFILES OF SPECIFIC HOOD CANAL COHO PRODUCING WATERSHEDS

2.6.6.1 Tahuya River

Watershed Area: 42.4 square miles
Length: 21.1 miles
Major Tributaries: Howell Lake, Haven Lake Collins Lake, Erdman Lake, Lake Wooten, Twin Lakes, Blacksmith Lake, Panther Creek, Morgan Marsh, Tahuya Lake, Gold Creek, and Tin Mine Creek.
Land ownership: Washington State Department of Natural Resources and private.
Major Land Uses: Commercial timber, ORV trails, campgrounds, Christmas tree production, farming, rural and residential.

Summer low flow may be the most important limiting factor for coho production. Unauthorized motorbike crossings, and horse trails also contribute to the damage of stream bank integrity and the stream bed. Within the drainage, encroaching hobby farms and residential developments are inevitably removing riparian areas. Christmas tree farms and commercial timber operations limit LWD recruitment to the stream.

A horse farm in the flood plain contributes to water quality problems. Increased housing within the drainage may be contributing to water quality problems with failing septic systems. Christmas tree farms also use a wide array of chemical pesticides.

The Tahuya River system has many wetland areas in the upper drainage that provide very good salmonid rearing habitat. The upper section of the drainage is dammed, creating a reservoir that provides for recreational use. The Tahuya is the largest stream system in the Lower Hood Canal Kitsap Peninsula watershed and occupies an extensive glacial outwash channel. The headwaters at the base of Green

Mountain originate from Tin Mine Creek, Gold Creek and associated wetlands. Stream gradients quickly drop to less than 5 percent. The majority of the upper tributaries are in glacial till material, which is moderately erodible and varies in composition. The river is actively meandering and deposits much of its load as sand and gravel bars along its length. Minor bank erosion is naturally occurring in this type of stream morphology. A broad alluvial valley has developed near the mouth of the river (Kilian 1990).

The primary land use along the stream corridor is commercial and private forest land (82 percent). Christmas tree farms occur along seven percent of the corridor and residential land use occurs along three percent of the streams and tributaries.

The majority of the stream corridors of the Tahuya River system remain in a natural wooded condition. Exceptions to this are lake developments and scattered residential parcels. Portions of the mainstem and its tributaries have a shallow gradient and numerous swampy low gradient sections with many beaver ponds. These areas also exhibit dense stream bank cover and provide favorable conditions for rearing and over wintering habitat of juvenile salmonids. Animal access to the stream corridors, although not extensive, occurs in a few areas. Those areas that do allow animals access to the streams are a source of sediment and bacteria. Stream fencing and restricting animal crossings would be beneficial to water quality.

The major source of sediment found within the stream corridors of the Tahuya River and its tributaries are the numerous off-road vehicle trails and wet crossings. The problem is not the maintained trails and bridges at stream crossings, but the many unauthorized trails and crossings. These numerous trails are the primary source of sediment to the stream. The usual site for illegal crossing is in riffle areas since this is the shallow portion of the stream. These riffle areas are the spawning grounds for salmonid species. While adult salmon are only present in the streams from September to January, the eggs and young will continue to live in the gravel until March or April. Crossings of the streams during this time period can kill many eggs and young developing fish. There is some evidence that disturbances of stream bed gravel in a riffle will attract adult salmon to the area for spawning. This has the potential to create greater problems at stream crossings. In addition to egg mortality caused directly by crushing, eggs and young can be suffocated by sediment stirred up during the crossing or killed by seismic shock.

2.6.6.2 Dewatto River

Watershed Area: 18.4 square miles
Length: 8.7 miles
Major Tributaries: Cady Lake, Oak Lake, Shoe Lake, Larson Lake, Ludvick Lake & Creek, and Erickson Lake.
Land ownership: Private.
Major Land Use: Timber, Christmas trees, hobby farms, and ORV campground.

Summer low flows may be the limiting factor for Dewatto. Dewatto Bay Road has an active road slide just above the south shore of Dewatto Bay. The road was reconstructed and resurfaced, but no stabilization was attempted on the eroding bank. Timber harvest and forest lands conversions have been on the increase within this drainage, but the Dewatto system remains largely undeveloped. Hobby farms in the drainage may contribute to non-point pollution.

The Dewatto River drainage is located on the eastern shore of Hood Canal, flowing in a southwesterly direction and parallel to the Canal. The Dewatto River provides some of the most pristine salmon habitat remaining in Hood Canal. Animal access to the stream corridor, allowed by a few farms, impacts the habitat. Although sparsely developed, the recent addition of power lines to the area may provide for increased development in the near future. Several tree farms are located in the watershed and border six percent of the river and its tributaries. The primary land use along the stream corridors is commercial and private forest land.

The primary sources of sediment and bacteria found within the stream corridor are the few farms permitting animal access to the streams. Development of farm management plans in addition to fencing of the corridor restricting animal access is needed.

2.6.6.3 Union River

Watershed Area: 23.5 square miles
Length: 9.7 miles
Major Tributaries: Courtney Creek, Bear Creek, East Fork Union River, Hazel Creek.
Land ownership: Private.
Major Land Use: Timber, Christmas trees, hobby farms, and ORV campground.

Summer low flows may be the limiting factor for the Union River watershed. Loss of riparian areas has resulted from development and increasing pressures of urbanization. Increasing land clearing and urbanization in the drainage may contribute to non-point pollution. Toxins from the Olympic View Landfill leach into the Union River and lower Hood Canal. The City of Bremerton also has a water supply reservoir at the upper end of this drainage. Some wetland areas at the mouth of the river have been "set-aide" as preserved areas and should help to ensure the future protection of the lower Union River watershed.

The Union River headwaters lie in Kitsap County near the 1,500 foot elevation. As the river leaves Gold Mountain, it enters the broad valley of the glacial outwash channel where stream gradients decrease to less than three percent. The valley material is composed of outwash silt, sand and some gravel. The majority of the material that is eroded and transported downstream is deposited near the mouth as alluvial flood plain and mud flat sediments.

Access to the upper watershed is restricted by the City of Bremerton because of the Union Reservoir which is the domestic water supply for the City of Bremerton and surrounding communities. The stream corridors in this upper section are all forested. The gradient is moderate to steep and anadromous fish passage is restricted by a falls located 6.7 miles from the mouth of the river. Below the falls the gradient is moderate and becomes more shallow with sections of very slow current in the lower five miles.

The lower Union River is a broad valley with moderate residential development. The majority of the small farms in the entire Lower Hood Canal watershed are located within the Union River valley. The Union River enters Hood Canal at Lynch Cove near Belfair.

Some animal access to the stream corridor occurs and, although not extensive, these areas are a source of bacterial contamination and sediment. All of the parcels with animal access are small farms and no commercial animal operations are found within the Union River drainage. Fencing is recommended to restrict animal access and development of animal management plans would be beneficial.

The East Fork of the Union River consists of wetlands in the lower reaches. The upper section the East

Fork is dry most of the year. Some runoff occurs during high rainfall periods. Sources of nonpoint pollution are the Olympic View landfill operation and the application of sludge effluent on the City of Bremerton's land near the East Fork of the Union River. Past water quality sampling has revealed high bacterial counts in the lower section of the river. Failed septic systems and stormwater runoff have been determined to be the most likely source.

2.6.6.4 Skokomish

Watershed Area: 240.0 square miles
Length: 41.9 miles
Major Tributaries: Purdy Creek, Hunter Creek, Vance Creek, Kirkland Creek, Fir Creek, Aristine Creek, Cabin Creek, Rock Creek, Harp Creek, Brown Creek, LeBar Creek, Cedar Creek, Pine Creek, Church Creek, Steel Creek, Rule Creek, McTaggert Creek, Gibbons Creek, Dow Creek, Kokanee Lake, Lake Cushman, Deer Meadow Creek, Big Creek, Dry Creek, Bear Creek, Elk Creek, Slate Creek, Four, Five, Six, Seven, Eight,and Nine Stream.
Land ownership: Olympic National Park, Olympic National Forest, Washington State Department of Natural Resources, Simpson Timber, and other Private.
Major Land Use: Timber, Christmas trees, farms, recreation, hydroelectric, residential and fish hatcheries.

Summer low flows are increasing in severity due to stream bed aggradation, which is caused by increased winter peak flows from logging activities, including extensive road building in the forest lands of the watershed. Many tributary stream flows go partly or completely subsurface during summer. Loss of riparian areas has resulted from diking, filling and development. Overflow channel habitats have been reduced. Stream bed aggradation is causing increased overbank flooding, which in turn contributes to increased erosion especially during winter high flow events. Unstable substrate may be contributing to loss of survival of egg to emergent fry. Fine sediment within gravels may also be reducing survival of fry. Removal of flow from the North Fork Skokomish has reduced mainstem flow by 40%. Loss of sediment transport capacity has reduced effectiveness of the river to maintain the historic river channel. Alteration of sediment transport in the delta area is causing a reduction in productive capacity of the estuary for juvenile fish. Critical nearshore areas adjacent to the Skokomish River delta were filled when the Cushman Hydroelectric Powerhouse No. 2 was constructed just west of the mainstem river mouth.

Livestock within the Skokomish River Valley with access to tributary streams are a potential source of non-point pollution. Hatcheries within the watershed also may contribute to chemical and biological pollution. Unstable stream beds, erosion of riverbanks, and runoff from roads also add to the suspended sediment loading of the system.

2.6.6.5 Little Mission Creek

Watershed Area: Unknown
Length: 2.1 miles
Major Tributaries: none
Land ownership: Washington State Department of Natural Resources and private.
Major Land Use: Timber, Christmas trees, hobby farms, recreation, and residential

Summer low flow may be the limiting factor for fish production, but more data needs to be collected. Christmas tree farms and commercial timber operations limit LWD recruitment to the stream. Increased recreational use with unauthorized motorbike crossings may impact water quality.

Little Mission Creek empties into Hood Canal at the west end of Belfair State Park. The stream flows through a gently sloping valley with a moderate gradient and has excellent stream bank cover. Above the park the stream flows through a short, but high density residential area, although the upper part of the watershed is almost entirely forested.

Little Mission Creek is small in comparison with the drainage area of the Union and Big Mission Creek, but provides important rearing habitat for juvenile coho salmon during the dry summer and fall months. This small stream is an important producer of coho salmon. This stream is also aggrading in the lower reaches within the State Park. Sections of the stream are dredged each year to remove some of the accumulation of gravel.

2.6.6.6 Big Mission Creek

Watershed Area: Unknown
Length: 9.8 miles
Major Tributaries: Mission Lake
Land ownership: Washington State Department of Natural Resources and private.
Major Land Use: Timber, Christmas trees, hobby farms, recreation, and residential

Big Mission Creek empties into Hood Canal at the east end of Belfair State Park. The upper sections of the watershed contain several lakes. Residential development is sparse and scattered throughout the drainage except around the lakes where such development is of higher density. Commercial and private forest land comprise 84 percent of the land use along the stream system.

The headwaters of Big Mission Creek are in wetlands at the base of Gold Mountain. Channel gradients are typically less than five percent the entire length of the creek. The main stem of the Creek is in glacial advance and recessional outwash sediments, which consist of unconsolidated silt, and gravel, all of which is highly erodible. Most of the eroded material is deposited in the stream channel as sand and gravel bars and as a small delta at the mouth in Hood Canal (Kilian 1990).

The primary limiting factor for salmonids are the low stream flows during the dry months. Off-road vehicle trails near Goat Ranch Road are a major source of sediment within the stream corridor. Many unauthorized "bootleg" trails are present. As discussed within the section on the Tahuya River, stream crossings are harmful to fish eggs within the gravel of the streams and to newly hatched fry. Enforcement of regulations restricting off road vehicles to established trails and bridges is needed to protect fish habitat and water quality.

2.6.6.7 Caldervin, Shoofly, and Little Shoofly Creeks

All three of these streams empty into the north shore of Hood Canal and support small runs of coho salmon. These creeks are actively cutting down through the glacial advance outwash silt, sand and gravel deposits. These streams erode and transport relatively large amounts of sand and gravel downstream to be deposited at their mouths in Hood Canal. The stream flow for these creeks is mostly dependent on groundwater recharge. With increasing amounts of groundwater withdrawal by residential developments, the flows of these creeks decrease during times of low precipitation, and the stream beds aggrade (Kilian 1990).

These streams share an accumulation of large size sediment (sand and gravel) in the lower reaches. This accumulation of sediment causes flooding near the outlets. During periods of high runoff the additional water spills over the stream banks. Normally the streams would cut a new channel, but residential development in the flood plain restricts any natural meandering by the streams.

The land cover along most of the corridors is forested. Several areas in the upper parts of the watershed support Christmas tree farms. The lower reaches of the streams near the mouths are bordered on both sides by residential development.

2.6.6.8 Kitsap County: Gamble, Lofall, Bangor, Little Anderson, Big Beef, Seabeck, Stavis, Boyce, and Anderson Creeks

Watershed Area: 92 square miles
Maximum length: 12 miles
Land ownership: Port Gamble S'Klallam Tribe (20%), Washington State Department of Natural Resources (20%), U.S. Navy Bangor Submarine Base (20%), Private (50%)
Major land use: Suburban and rural residential, pasture, farm, and forest

Several of the streams in western Kitsap County have been influenced by hatchery production including facilities located directly at the streams or outplants of hatchery reared fry, fingerlings, and smolts. In general, watershed developments and residential groundwater use have contributed to low summer flow and high winter peak flow situations. The watersheds also exhibit excessive sediment loading, lack of LWD, lack of pools, degraded riparian corridors and abnormally high water temperatures. Many of the culverts have poor fish passage conditions. It is expected that increased residential and commercial development will continue to impact summer low flows and winter peak flows, increase the potential for non-point pollution, contribute to sedimentation and continue the degradation of riparian zones.

2.6.6.9 North Jefferson County: Squamish, Thorndike, Tarboo, and Chimacum Creeks

Watershed area: 120 square miles
Maximum stream length: 13 miles
Land ownership: Washington Department of Natural Resources (30%), Pope Resources (40%), and other private (30%)
Major land use: Timber, suburban and rural residential, farm

Extremely low summer flows and very high winter peak flows occur in these watersheds due to continuing residential development and groundwater withdrawals. Logging activities have contributed to excessive sediment loading and aggradation. Wetlands located in the flood plain have been extensively channelized to provide for pastures. The developments have also contributed to a lack of LWD and "pool" habitat. Culverts are not maintained and riparian corridors have been degraded. It is expected that increased residential and commercial development will impact summer low flows, winter peak flows, and increase non-point pollution, sedimentation, and riparian zone degradation.

2.6.6.10 South Jefferson County: Donavon Creek, Little Quilcene, Big Quilcene, Dosewallips, and Duckabush Rivers

Watershed Area: 180 square miles
Maximum stream length: 25 miles

Land ownership: Olympic National Park (30%), Olympic National Forest (50%), Washington State Department of Natural Resources (10%), private (10%)
Major land use: Industrial forestry, National Park, farm, pasture, suburban

The watersheds in South Jefferson County suffer from excessive sediment loading and aggradation due to logging on both the National Forest and private lands. The streams also lack suitable LWD and "pool" habitat. Diking and dredging of the lower river flood plain has occurred for flood control. Residential development on the lower river riparian areas and side channels have resulted in extensive loss of salmon habitat. Large lot subdivisions are being proposed for the watersheds which will impact summer low flows and winter peak flows, increase non-point pollution, sedimentation and riparian zone degradation.

2.6.7 RECOMMENDATIONS

Habitat factors limiting salmon production in Hood Canal streams are known only in general terms. Many adverse environmental impacts are occurring and will continue to occur throughout the Hood Canal watershed. Major projects such as hydroelectric projects, though developed several years ago, may just now be starting to impact the once productive capacity of Hood Canal coho salmon habitat. Accelerated human growth in the Hood Canal area can also be assumed to have some impact upon coho salmon production. Cumulative impacts are poorly understood, though recognized in concept. It is incumbent upon any evaluation of Hood Canal coho salmon to understand the status of the habitat and develop prescriptions to prevent degradation and, where possible, increase the productive capacity. Current habitat protection regulations are insufficient to prevent further loss of critical salmon habitat. Local and regional government with jurisdiction in Hood Canal must recognize the need to manage growth and initiate programs that can provide for the restoration of fish habitat.

Development of a comprehensive approach should be designed to protect and rehabilitate the productive capacity of Hood Canal coho salmon habitat to its fullest potential. The intent of such an approach would be to develop a process that is designed to prevent continuing incremental degradation of the habitat and to promote watershed restoration so that wild stock management continues to be a viable option for the long term. Specific recommendations regarding the comprehensive approach for Hood Canal coho salmon habitat includes:

- ***Determine what other information is available regarding the productive capacity of the habitat in Hood Canal. Alternative, more recent data sources should be reviewed and integrated into a habitat database available for all resource agencies involved in the protection and restoration of Hood Canal coho salmon habitat.***

- ***Review federal, state, and local riparian, wetland, and shoreline protection standards to determine the level of habitat protection and enforcement efforts across jurisdictional boundaries. Determine the effectiveness and consistency of current regulations in protecting habitat in the Hood Canal watershed. Local, Tribal, State, and Federal governments and natural resource agencies should develop a comprehensive approach to habitat protection and restoration on a watershed by watershed basis within Hood Canal and on a regional Hood Canal basis. The various jurisdictions need to develop a coordinated approach to maintain consistency and address habitat issues which are generally of a regional nature.***

- ***Develop a quantified inventory of current habitat conditions with respect to productive*** *capacity. The quantification is essential to provide an objective measure of habitat quality and quantity and in order to evaluate the current status of the freshwater habitat in the Hood Canal watershed.*

- *Develop and implement watershed recovery plans with the objectives of rebuilding and protecting coho salmon stocks throughout Hood Canal. The watershed recovery plans will summarize existing habitat information and outline specific steps that will need to be taken including; regulatory changes, enhancement and restoration efforts, and additional information required to achieve any desired future conditions for Hood Canal coho salmon habitat. The plan should also specify timelines, responsible parties, and evaluation methods for judging the effectiveness of the watershed recovery plans.*

2.7 GENERAL RECOMMENDATIONS

Adequate and effective management of fisheries resources requires consideration of all major influences on stock abundance and survival. These influences include harvest, escapement, and both freshwater and marine survival and production. Freshwater habitat quality and quantity is a key component which determines freshwater survival and production. However, habitat condition is not routinely or consistently assessed by fisheries management agencies. The management of habitat is also diffuse among a number of land management agencies who are neither clearly responsible for, nor experience in, fisheries habitat assessment and management. The effort to solve habitat related problems must therefore be a collective one. Government at all levels has a role to perform, as do fishermen, industry, sports and recreational organizations, environmental groups, and others interested in the future of our fisheries resources. It is important for collaborative efforts to assess and protect fish habitat to continue and increase in the future.

We recommend the following actions:

- *Develop a comprehensive resource and habitat assessment for all watersheds, that includes a general inventory of current habitat and the identification of factors limiting fish production and survival. These assessments could be coordinated with watershed analyses being conducted within Washington State by the Department of Natural Resource and Timber/Fish/Wildlife Cooperators.*

- *Tribal and state fisheries management agencies should develop a coordinated long term program to monitor the status of fish populations, stream habitat, and effectiveness of habitat protection and restoration efforts. The program should be established with the goal of improving our knowledge regarding the quantitative relationship between land use, habitat condition, and fish production.*

- *Local, tribal, state, and federal governments should develop a comprehensive coordinated approach to habitat protection and restoration on a watershed or regional basis. The assessments discussed in recommendations 1 and 2 would serve as the basis for developing such watershed protection programs.*

- *The PFMC should request specific actions from federal, state, local and tribal governments to protect habitat for stocks of concern. PFMC comments should be directed to permitting and policy processes which include, but are not limited to the following:*

* *federal and state wetlands regulation and policy development*
* *review of Best Management Practices (BMP's) for agriculture and forestry*
* *hydroelectric facility permitting*
* *forest practices on federal and state regulated lands*
* *flood control projects such as diking, dredging, and flood control reservoirs*

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2.9 REFERENCES CITED

Bjornn, T.C. and D.W. Reiser. 1991. Habitat Requirements of Salmonids in Streams. In Influences of Forest and Rangeland Management on Salmonid Fishes and Their Habitats, American Fisheries Society Special Publication 19:83-138.

Chamberlin, T.W., R.D. Harr, and F.H. Everest. 1991. Timber Harvesting, Silviculture, and Watershed Processes. In Influences of Forest and Rangeland Management on Salmonid Fishes and Their Habitats, American Fisheries Society Special Publication 19: 181-205

Kilian, K. Y. 1990. Lower Hood Canal Watershed Geology and Geomorphology. U.S. Department of Agriculture Soil Conservation Service. Spokane, Washington.

Murphy, M.L., et al., 1985. Role of Large Organic Debris as Winter Habitat For Juvenile Salmonids in Alaska Streams. In Proceedings: Western Association of Fish and Wildlife Agencies 1984. p. 251-262

OFM. 1990. 1990 Population Trends for Washington State. Office of Financial Management, Forecasting Division, Olympia, WA. 63 p.

OFM. 1991. Washington State 1991 Data Book. Office of Financial Management, Olympia, WA. 306 p.

OFM. 1991a. 1991 Population Trends for Washington State. Office of Financial Management, Forecasting Division, Olympia, WA. 128 p.

OFM. 1992. Washington State County Population Projections 1990-2010. Office of Financial Management, Forecasting Division, Olympia, WA. 11p.

PSWQA (Puget Sound Water Quality Authority). 1986. State of the Sound Report. Puget Sound Water Quality Authority, Seattle, WA. 225 p.

SSC. 1992. Estimating habitat and coho salmon production losses due to flood protection in the Skagit River basin. Draft report, Skagit System Cooperative, LaConner, WA.

USFS. 1991. Preliminary Timber Resource Statistics for the Puget Sound Area, Washington. USDA Forest Service, Pacific Northwest Research Station, Resource Bulletin PNW-RB-179, August, 1991.

Scheffer, Theodore H. 1928. Precarious Status of the Seal and Sea Lion on Our Northwest Coast. Journal of Mammology, Vol. 9, No. 1, February 1928.

WDNR. 1988. Washington Timber Harvest - 1988. Washington Department of Natural Resources, Forest Regulation and Assistance, Olympia, WA.

WDNR. 1990. Fiscal Year 1990 Summary of Timber Sold, Removed & Remaining. Washington Department of Natural Resources, Division of Timber Sales, Olympia, WA.

WDNR. 1991. Forest Practices Program 1991 Calendar Year Report. Washington Department of Natural Resources, Forest Practices Division, Olympia, WA. 23p.

WDNR. 1992. Forest Practices Program 1991 Calender Year Report. Washington Department of Natural Resources, Forest Practices Division. 23 p.

WDOE. 1991. Report on Water Right Administration: Assessment of Issues/Action Program. Washington Department of Ecology, Water Resources Program, Olympia, WA. 44p.

Williams, R.W., R.M. Laramie, and J.J. Ames. 1975. A Catalog of Washington Streams and Salmon Utilization. Vol. 1, Water Resource Inventory Area (WRIA) 15, 16, and 17.

Zillges, G. 1977. Methodology for determining Puget Sound coho escapement estimates, 1977 pre-season run size prediction, and in-season run size assessment. Washington Department of Fisheries Technical Report No. 28. 65 p.